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MINUTES OF PROCEEDINGS
OF THE
INSTITUTION
OF
CIVIL ENGINEERS;
WITH
ABSTRACTS OF THE DISCUSSIONS.

VOL. XI.

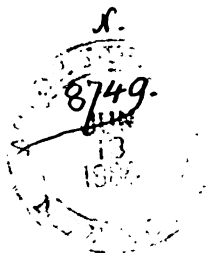
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SESSION 1851-52.  
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SECRETARY.

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INSTITUTION
OF
CIVIL ENGINEERS.

SESSION 1851-52.

November 11, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

No. 851. "An investigation of the Strains upon the Diagonals of Lattice Beams, with the resulting Formulæ."* By WILLIAM THOMAS DOYNE, Assoc. Inst. C. E., and WILLIAM BINDON BLOOD, A.B. (Professor of Civil Engineering, Queen's College, Galway.)

IN constructing a model, for the purpose of illustrating, practically, the truth of the mathematical reasoning, upon the strains to which the different parts of a lattice beam were subjected, under the same and different forms of load, it was the object of the Authors, to reduce the investigation to as simple a form as possible; they therefore constructed the model with catenated top and bottom strings, connected together by diagonals, forming a single triangulation, purposely avoiding the more complex form of a number of lattices intersecting each other.

The arrangement of the diagonals is such as to show, that with a beam supported at each end and loaded at the centre, or uniformly over its entire length, the strain upon the diagonals divides itself at the centre, and is transmitted through the two halves of the beam, in opposite directions, towards the ends, causing the diagonals in each half to act alternately as struts and ties; those acting as struts, in the model, being made of mahogany bars 14 inches long by $1\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch thick, with their ends simply let into the top and bottom strings, but not made fast in any way; while the ties are made of light hoop iron chains, each in three parts, put together

* The discussion on this Paper extended over a portion of two evenings, but an abstract of the whole is given consecutively.

[1851-52.]

with loose pins passing through them, and fastened to the top and bottom by the iron pins, which connect the parts of which they are formed; this arrangement preventing the possibility of the struts acting as ties, and *vice versa*.

The length of the model, between the points of support, is 154 inches (12 feet 10 inches), the triangles formed by the lattice bars are equilateral, each side being 14 inches long, making the depth from centre to centre of the top and bottom 12·124 inches. Its total weight is 22 lbs., and any portion of it can be taken out, so that a dynamometer can be inserted, by which means the strains upon all the parts have been measured, and compared with those calculated.

The following are the results (for a beam having a parallel top and bottom):—

With a load at the centre, the horizontal strains are greatest at the centre, decreasing towards the ends, in the ratio of the distance from the centre, while the strains upon the diagonals are uniform throughout the beam.

With an uniform load, the horizontal strains are greatest at the centre, decreasing towards the ends, in the ratio of the ordinates of a parabola, while the strains upon the diagonals commence at the centre, increasing towards the ends, as their distances from the centre.

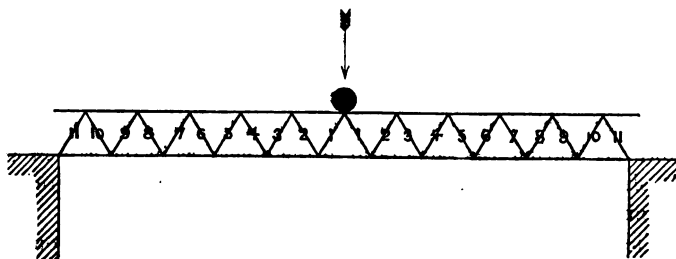
The course of reasoning by which these conclusions are arrived at, is very simple. The value of the horizontal strains does not require proof here, and those upon the diagonals are easily deduced from them, in the following manner:—With a beam supported at each end, and loaded at the centre, the horizontal strain commences at the point of support, increasing uniformly towards the centre, where the connecting rib between the top and bottom is continuous; but when, as in this case, there are intervals between the points of attachment, the increase is sudden, at each point of attachment, but of equal value; it is then evident, that as the horizontal strains are produced by the diagonals, that by differentiating the known horizontal strains, at the points of attachment of the diagonals, the amount of strain due to each diagonal is shown; in this case, the difference between the horizontal strain, at each point of attachment, is a constant number, consequently the strains upon the diagonals are uniform; or, in other words, the strains upon the diagonals are as the differences between the ordinates of two converging lines, which is the figure which would represent the strains upon the top and bottom.

For the same reason it is evident, that with an uniform load the

strains upon the diagonals decrease from the point of support, where they are greatest, towards the centre, as the differences between the ordinates of a parabola, which differences are the ordinates of two converging lines.

Or the same conclusions may be arrived at, without a knowledge of the horizontal strains, by tracing, through the medium of the resolution of forces, the strains produced upon the lattices by any given load; when it will appear, that with a load at the centre, as in Fig. 1, one-half is resolved in each direction, first through the

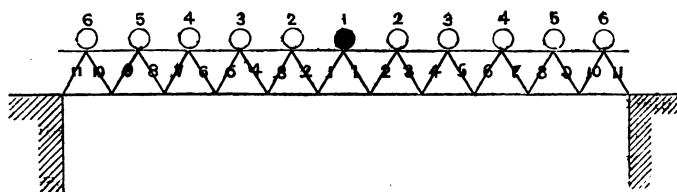
Fig. 1.



struts 1, 1, thence into the ties 2, 2, and from thence into the struts 3, 3, and so on alternately, through struts and ties until it reaches the point of support; the strain upon each lattice being uniform, and equal to half the load applied, increased by as much as the lattice bar is longer, than the perpendicular of the triangle of which it is the hypotenuse. The horizontal strain, produced at the points of attachment of each lattice, will also bear, to the strain upon the lattice, the ratio which the length of the base of the same triangle bears to the length of the lattice bar, and the total horizontal strain, at any point, will be the sum of the strains produced by all the lattices, between the point of support and that point, which will give the horizontal strains, as decreasing from the centre to the ends, in the ratio of the ordinates of two converging lines,—the premises which were the basis of the last mode of reasoning.

For a beam uniformly loaded, as in Fig. 2, weight No. 1 will, in

Fig. 2.



the same manner as in the last example, produce an uniform strain upon all the lattices, from 1 to 11, equal in amount to one-half its own weight, increased in the ratio before mentioned; weight No. 2 will resolve the whole of its weight (subject to the same increase), through all the lattices from 3 to 11; weight No. 3, in like manner, will give a new strain from 5 to 11, and so on, to the end, the strains accumulating, from the centre towards the ends, as the distance from the centre. Taking the sum of these strains at each point of attachment, the horizontal strains will be found to decrease, from the centre towards the ends, in the ratio of the ordinates of a parabola, as before assumed.

The same reasoning is applicable to the usual lattice beam, where the lattices intersect one another at several points; in this case, the horizontal strains are the same, except that they are distributed over a greater number of points of attachment, the strain at each point, however, bearing the same ratio to the others, as in the case of the simple triangulation, but the amount is decreased in proportion as the number of points of attachment have been increased.

The following rules and formulæ are at once deducible from the foregoing:—

With a load at the centre, the sum of the strains upon the lattices is equal to the horizontal strain at the centre, increased by as much, as the lattice bars are longer, than the bases of the triangles of which they form the hypotenuses, or the base of this triangle is to the hypotenuse, as the horizontal strain, at the centre, is to the sum of the strains, upon all the lattices, between the centre and one end; and as in this case, the strains upon the lattices are uniform, this total strain, divided by the number of lattices, between the centre and the end, will give the strain upon each.

For an uniform load, the sum of the strains upon the lattices, bears the same ratio to the horizontal strain, in the centre, but is differently distributed over them, as before shown; for in this case, the whole strain divided by the number of lattices, will give the strain upon that bar, which is situated half way between the centre of the beam and the point of support, while the strain upon the bar, at the point of support, is double the strain so found, and the intermediate strains can be calculated accordingly.

The strains upon the different parts of the model have been calculated, according to these principles, from the following formulæ:—

With a load at the centre, the horizontal strain at the centre is $s = \frac{W L}{4 D}$, and at any other point $s = \frac{W L}{4 D} \cdot \frac{2 x}{L}$, where W = the

weight, L = the length, D = depth, and x = the distance of the point from the abutment; and the strain upon any diagonal is

$y = \frac{Wb}{2D}$, where y = the strain, b the length of the diagonal, and WD as before.

With an uniform load, the horizontal strain at the centre is $s = \frac{WL}{8D}$, and at any other point $s = \frac{W}{2DL} (Lx - x^2)$, where x is the distance of the point from the abutment, and W, D, L as before; and the strain upon any lattice is $y = W \frac{ab}{DL}$, where

y = the required strain,

a = the distance of the middle point of the lattice from the centre of the beam,

b = the length of the lattice-bar,

and W, D, L as before.

These formulæ refer to a beam of a single triangulation, such as the model, the strain upon each lattice decreasing where the lattices intersect one another in the exact ratio of their increased number.

The following table shows, in adjacent columns, the strains upon the diagonals of the model, calculated by these formulæ, and those measured by the dynamometer, taken with the weight of the model alone, and also with weights applied in four different forms, by which it will be seen, that the calculations agree in a remarkably close degree with the measured results.

STRAINS upon the Diagonals of the MODEL, as calculated by the Formulæ, and as indicated by the Dynamometer.

Number of Lattice, reckoning from the Centre, Figs. 1 & 2.	Strain with its own Weight.		Strain with 77 lbs. at Centre.		Strain with 14 lbs. at each point of Top.		Strain with 14 lbs. at each point of Bottom.		Strain with 7 lbs. at each point of Top and Bottom.	
	Indicated.	Calculated.	Indicated.	Calculated.	Indicated.	Calculated.	Indicated.	Calculated.	Indicated.	Calculated.
1	..	·6	..	44·6	..	8·7	..	·6	..	4·6
2	1½	1·7	45	45·7	9½	9·8	17	17·9	13	13·8
3	..	2·9	..	46·9	..	27·1	..	19·1	..	23·1
4	4	4·0	47	48·0	28½	28·25	34	36·3	31½	32·3
5	..	5·2	..	49·2	..	45·6	..	37·5	..	41·6
6	6	6·3	48½	50·3	46	46·7	54	54·8	50½	50·8
7	..	7·5	..	51·5	..	64·1	..	56·0	..	60·0
8	8½	8·7	51½	52·7	65½	65·3	73	73·4	69	69·3
9	..	9·8	..	53·8	..	82·5	..	74·5	..	78·5
10	11½	11·0	57½	55·0	87	83·7	95½	91·8	91	87·8
11	..	12·1	..	56·1	..	101·0	..	92·9	..	97·0

By the application of these principles to practice, in bridges, or other beams, the correct proportion, that each lattice bar should bear to the remainder of the girder, is easily ascertained, as also the dimensions of the rivets, which connect the lattices with the top and bottom.

If the beam is required to carry an uniform stationary load only, then the lattices may be infinitely small, at the centre, increasing in strength, or number towards the ends, as their distance from the centre.

If for a load at the centre only, the lattices should be of uniform strength throughout.

If, however, as is generally the case in practice, the beam is required to carry both these descriptions of load, as well as one at any other point, then at the centre, the lattices should be of such dimensions as to resist the strain, produced by the greatest load which can be applied, at the centre, or at any other point, and to increase towards the ends, so as to meet the highest strains produced by an uniform load.

For girders, having boiler-plate, or other description of solid sides, the same principles apply, and point out, that for a load, at one point only (leaving out of consideration, as in all these other cases, the weight of the beam itself), the dimensions of the sides, and the connecting rivets, should be uniform throughout; while for an uniform load, the sides and rivets should increase in strength, from the centre towards the ends, in the ratio of the ordinates of two converging lines; the correct proportions for any other description of load, being also easily estimated, by an extension of the same principles.

The Paper and Appendix were illustrated by a model and a series of diagrams, from which Figs. 1 to 9 have been taken.

APPENDIX.

Most of the following formulæ, giving the strains upon the diagonal bars of diagonally-framed beams, were arrived at before the construction of the model, which was made for the purpose of practically verifying them.

The formulæ are given without any mathematical demonstration, as this is easily supplied by those who desire it.

Case I. (Fig. 3.) Semi-beam loaded at the extremity.

Let w = weight,

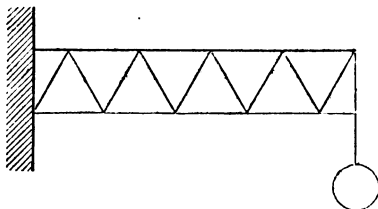
λ = length of diagonal bars,

d = depth of beam,

Σ = strain of diagonal,

then $\Sigma = w \frac{\lambda}{d}$, and is uniform throughout the beam.

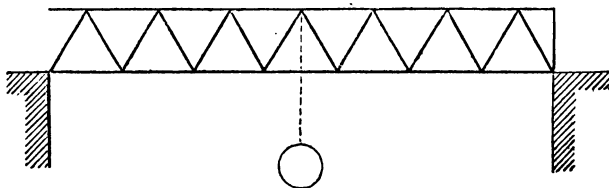
Fig. 3.



Case II. (Fig. 4.) Beam supported at the ends and loaded in the middle:

then $\Sigma = \frac{1}{2} w \frac{\lambda}{d}$ also uniform.

Fig. 4.



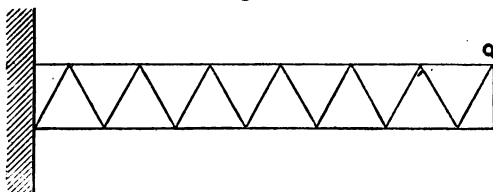
Case III. (Fig. 5.) Semi-beam uniformly loaded.

Let μ = load on unit of length,

κ = distance of diagonal from a ,

then $\Sigma = \mu \kappa \frac{\lambda}{d}$ varies as κ .

Fig. 5.

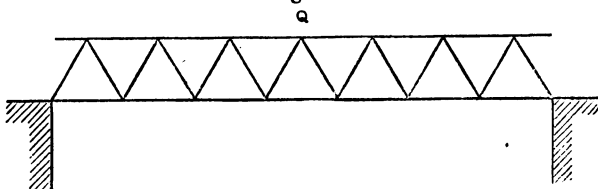


Case IV. (Fig. 6.) Beam supported at the ends and uniformly loaded.

Let x = distance from Q , the centre,

$$\text{then } \Sigma = \mu x \frac{\lambda}{d}.$$

Fig. 6.



It is easy to extend these formulæ to the cases of continuous beams; thus (Fig. 7.)

In a beam AB supported at the ends and the middle point and uniformly loaded.

Let Q be the point of maximum horizontal strain, AQ being $\frac{1}{3}$ of AB .

Let x = distance from Q ,

$$\text{then } \Sigma = \mu x \frac{\lambda}{d}.$$

Thus the strain increases uniformly from Q both ways to A and B , where it is a maximum.

This formula applies to all cases of continuous beams, x being always measured from the point of maximum horizontal strain in each span.

In all these cases of uniform loading x is measured to the upper end of the diagonal, if the load be attached to the bottom of the beam; to the lower end of the diagonal, if the load rest on the top of the beam; and to the middle point of the diagonal, if the load be supported equally by top and bottom.

Fig. 7.



Let AB (Fig 8), be a beam of diagonal framing supported at A and B .

Suppose a train of uniform weight, and whose length is not less than AB , to move from A towards B .

The maximum strain on a diagonal, at any point (m) in the half CB , is when the front of the train is at (m), and the maximum strain at (m') is when the tail of the train is at (m').

The strain on a diagonal at the middle point C is a maximum, when an end of the train is at C .

These maximum strains are proportional to the ordinates of the parabolas EQ and QF , whose vertices are at B and A respectively, and in which the ordinates AE and BF represent the strains at the extremities with uniform load.

The strain at (m) varies as $\frac{A m^2}{B m'^2}$,
 „ m' „ $\frac{A m^2}{B m'^2}$.

If, therefore, AE and BF be taken to represent the strains due to a uniform load of greatest density (say engines), and if AG and BH be taken equal to the strains due to the weight of the bridge itself, and the parabolas EQ and QF and the lines CG and CH be drawn, the ordinates of the figure $GEQFHC$ will represent the greatest possible strains upon the several diagonals.

From this it appears, that the greatest possible strain at the centre is one-fourth of that at the ends, due to the moving load alone.

To express these strains by formulæ,

let $x = Cm$ or Cm' ,
 $l = AB$,
 λ = length of diagonal bar,
 d = depth of beam,
 μ = density of constant load,
 μ' = density of moving load,
 Σ = strain on diagonal,

$$\text{then } \Sigma = \mu x \frac{\lambda}{d} + \mu' \frac{(\frac{1}{2}l + x)^2}{2l} \cdot \frac{\lambda}{d}.$$

If $x = 0$ we have at the middle point

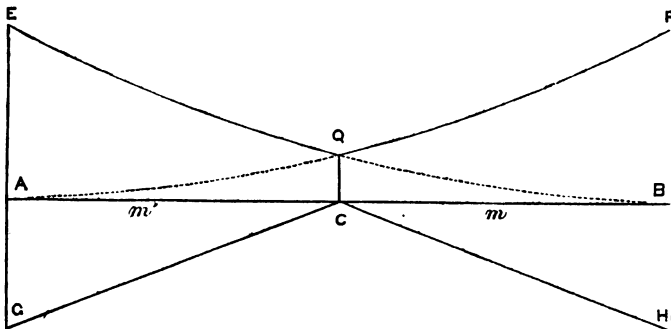
$$\Sigma = \frac{1}{8} \mu' l \frac{\lambda}{d}.$$

If $x = \frac{1}{2}l$ we have at the ends

$$\Sigma = \frac{1}{4} (\mu + \mu') l \frac{\lambda}{d}.$$

If the length of the train be less than AB the effect will be to diminish some of the strains towards the ends, so that the foregoing diagram and formulæ cover every case.

Fig. 8.



With respect to continuous beams there is one point deserving of notice, viz., the case of unequal loading of the different spans.

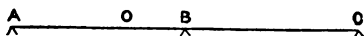
This is important, because it diminishes the advantage derived from continuity in all cases of moving loads.

For instance, in the case of a beam supported at the ends and middle point (Fig. 9),

if μ = unit of load on A B,
 μ' = " " B C,
 O the point of contrary flexure,
 then $AO = \frac{7\mu - \mu'}{8\mu} \cdot l$,
 the pressure on $A = \frac{7\mu - \mu'}{16} \cdot l$,
 " $B = \frac{7}{8}(\mu + \mu') \cdot l$,
 " $C = \frac{7\mu' - \mu}{16} \cdot l$.

The horizontal strain in AO is greater (if μ be greater than μ') than when the spans are equally loaded, and the diagonals towards A are more strained, and those towards B less so.

Fig. 9.



Analogous formulæ may be derived for the other cases of continuous beams.

As an example suppose a beam over two spans of 120 feet each.

With an uniform load, the point of contrary flexure is 90 feet from the extremity.

But if the load on one span is double that on the other, this point is 97.5 feet from the extremity of the beam.

Several very careful experiments have been made upon the deflection of steel bars, to test the accuracy of these formulæ and of those for the case of a beam on four supports.

The results of these were very satisfactory, the measured deflections agreeing very closely with those calculated from the formulæ.

Mr. DOYNE said his advocacy of the system of lattice construction was based upon careful theoretical investigation and practical experience, both by experiments on a sufficiently large scale and by the construction of bridges of considerable span. He had determined to enter thoroughly into the investigation of the subject, and therefore had, in conjunction with Mr. Blood, so constructed the large model, as that each strut and tie could be removed and, by the substitution of a dynamometer, the strain in any part could be measured. The experiments were in all cases made before the calculations and the coincidence between the results was remarkable. It would be observed, that the model exhibited equally well the effects of an uniform, or of a partial load, and as from the construction, the action of the struts and the ties could not be reversed, all the variation of the strains, consequent on the varying load, must be rendered palpable.

In the Appendix to the Paper (Page 7), Mr. Blood had given the various formulæ, used for different kinds of pressures.

Since this investigation had been made, Mr. Doyme had con-

structed, for the Aberdare Iron Company, a bridge, on this principle, of 140 feet span, for carrying a railway over the River Taff. It was originally intended only to bear one line of rails, but two lines had been laid down; the depth of the girders was 12 feet 6 inches; the lattice bars were made of plain flat rolled iron 3 inches by $\frac{1}{2}$ inch, for 14 feet in the centre and 4 inches by $\frac{1}{2}$ inch, for 14 feet at each end, put together with rivets $\frac{1}{2}$ inch in diameter. The bridge had frequently been loaded with 75 tons; which would give a strain of $6\frac{1}{2}$ tons per square inch of section on the bars. There was a regular traffic of about 100,000 tons per annum over it. As to the cost of construction; the Aberdare Company supplied the iron to Messrs. Brown, Lennox, and Co., who put the girders together on the spot, and raised them up to their positions by hydraulic press power. The total weight of iron employed was 53 tons, and the cost of the bridge was £11. 10s. per ton nett, which was £4. 7s. per foot run of the span, exclusive of the cost of erection and carriage.

Now comparing this with a box beam girder; the sectional area of the top and bottom must be identical in either case, and Mr. Doyne must contend, that the method of uniting them by the diagonal struts and ties, which were comparatively small pieces of cheap and easily handled rolled merchant bar iron, simply punched at the ends and at the intersections for the rivets, was a simpler and easier system, than riveting together a number of sheets of iron, which, taking weight for weight to cover that area, would be barely $\frac{3}{8}$ inch in thickness, and would therefore require nearly as much more metal for the angle irons, the overlap of the plates, and the stays to give the connecting web stiffness and to prevent it from buckling. Besides, there would be a considerable saving in the first cost of common bars, as compared with boiler plates, and the cost of labour must certainly be less in the diagonal construction than in the plate iron riveted web; thus he contended, that theoretically and practically, for girders of all dimensions, the system he had advocated did possess important advantages.

Mr. P. W. BARLOW said he had used girders of the triangular construction and was well satisfied with them, both as to cost and strength; for spans of moderate dimensions, he preferred the simple equilateral triangulation to the more complicated system of lattice-work; the calculation of the strength was easy, and, practically, that form offered great facility for construction.

Mr. DOYNE explained, that his reason for adopting the lattice form, instead of the simple triangulation was, that with deep girders smaller-sized bars and rivets were required, inasmuch as the points of suspension and attachment were closer together with the lattice

system, than with the simple triangulation, for which latter construction, in the case of wide spans, large dimensions of iron must be adopted, the pins would require to be very strong, and the holes must be cut out by expensive machines, instead of by a simple punching press. In deep girders, it was convenient to place the platform, or roadway, midway of the depth, which just suited the lattice form, but was not so convenient with the simple triangulation.

In answer to the President, he stated, he had only used the simple triangulation for spans not exceeding 60 feet and generally for shallow girders, but he believed that some girders had been made on Captain Warren's plan for much greater spans. The question between the simple and the close triangulation was, in a great measure, one of comparative cost of construction, and he was inclined in favour of the lattice form, chiefly because of its facility and economy.

Captain O'BRIEN directed attention to a bridge erected by Mr. Osborne at Ballysimon, on the Waterford and Limerick Railway;* the principle of construction, was stated to be simple, each girder consisting of a top and bottom cill, kept apart by cast, or wrought iron diagonal struts, intersecting each other and forming a double triangulation, with wrought-iron ties through the abutting pieces of each pair of struts. The platform was carried by transverse timber beams laid on the bottom cill; the clear span was 86 feet, and the cost, exclusive of the cross beams and platform was £1,289. Bridges of this principle of 50 feet span had been erected complete for £625.

It was stated, that there was not any dead weight, or useless material, that the pieces composing the girders were mere duplicates of each other, were easy to be handled, and required no skill in adjusting; the beams might be dead level, or be slightly cambered; they occasioned no thrust on the abutments, as they rested on rollers, to allow for contraction and expansion; the deflection of the bridge of 86 feet span was only $\frac{1}{8}$ inch, when tested by a weight of 80 tons.

Mr. DOYNE objected to the system of construction of the bridge just referred to, as under a varying load, some parts were completely relieved from pressure, whilst the others had an undue proportion thrown on them. Under all circumstances some of the struts were relieved from strain, which was borne by the ties; therefore the material employed in those struts was not only unserviceable, but it added to the load on the bridge.

Mr. C. MAX directed attention to the bridge on the single triangulation principle, now in course of construction, by Messrs. Fox,

* *Vide* Report of the Commissioners appointed to Inquire into the Application of Iron to Railway Structures, page 413. Folio, Plates. London, 1849.

Henderson, and Co., for carrying the Great Northern Railway across Newark Dyke: the span would be 250 feet and the diagonal ties would be nearly 17 feet long; he suggested that in the course of the next session, when the bridge was erected, it would be very desirable to have an account of it.

The PRESIDENT explained, that Mr. Joseph Cubitt was the Engineer of that railway, but he could promise on his behalf, that an account of the bridge should be furnished in the course of the next session.

Mr. HAWKSHAW said he had constructed many lattice bridges of various spans: an enumeration of a few of them, with some of their leading particulars, would suffice to give an idea of them.

The Paddock viaduct, near Huddersfield, which was 80 feet high, was constructed, in its centre part, of continuous beams of malleable iron lattice work 345 feet in length, 7 feet deep, and spanning four openings, each of 80 feet clear width.

The viaduct was built for two lines of rails; there was one girder under each rail and one on each side, forming the fence; making six girders altogether; they were braced transversely with lattice bracing, and the girders were covered with planking 6 inches thick, laid transversely.

The breaking weight of the girders, treating them as separate girders over each opening, was rather more than three times a load of $1\frac{1}{2}$ ton per lineal foot, on each line of way, and the cost of the iron work complete at £20 per ton was £15 per lineal foot.

The bridges over the Leeds and Liverpool canal and the canal wharf, at Liverpool, were also constructed of malleable iron lattice work, differently disposed from that at Paddock.

These bridges were in situations where there was only a depth of 2 feet between the level of the rails and the headway required to be left beneath the line, for the whole width of the openings.

There were four openings, one of 120 feet span, one of 112 feet span, and two of 70 feet span each.

Each opening was spanned by two double lattice girders, one on each side the lines of way: transverse plate iron girders 15 inches in depth were bolted to the bottom of these, and on them the two lines of railway were laid.

The large girders, for the span of 120 feet, were 12 feet deep in the centre, and diminished to 6 feet in depth at the ends. The other girders were proportionably of less dimensions.

In all these segmental lattice bridges, the breaking weight was calculated at fully four times a load of $1\frac{1}{2}$ ton per lineal foot on each line of way.

The cost per lineal foot at £17 per ton was—

	£.
In the 120 feet span	28
„ 112 „	25
„ 70 „	17

The lattice was, in many cases, a convenient and economical mode of connecting the top and the bottom ribs of a girder; the simplest and cheapest application of the principle was, when the platform could be placed on the girder; it was also less subject to casualty, than when the platform was placed at some distance up the sides.

Mr. BRUNEL, V.P., said, that in considering this question, it was necessary to draw a distinct line of demarcation between the lattice bridge and that kind of construction called Warren's girder; in the former much of the material employed was useless, whilst in the latter, if properly proportioned, every part was made to perform its duty, either bearing pressure, or in tension; he was inclined to think it might be rendered nearly the most economical, as well as the most efficient kind of girder, for spans of a certain extent.

Mr. RENDEL, V.P., said, that Mr. C. H. Wild had recently investigated carefully, for him, the proportions and scantlings of some bridges on Warren's principle, intended to carry the lines of railway in India; for which locality their simplicity of construction, being composed of multiples of a few parts, the ease with which they could be transported to their destination, and the facility of putting them together, peculiarly fitted them. They were also cheap; a bridge of a span of 220 feet would cost about 15 per cent. less, than a lattice bridge for the same span. It was necessary not to confound the two principles, as the Warren girder was decidedly superior to the lattice bridge.

November 18, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

No. 860. "Description of a new metallic Manometer, and other instruments for measuring pressures and temperatures." By EUGENE BOURDON (Paris).

THE Author's attention has been for several years directed to the subject of pressure gauges and similar instruments, with the view of obtaining a more simple and perfect, as well as a more convenient instrument, than those hitherto employed, and having, as he believes, succeeded in obtaining this object, he desires to place the results of

his researches before the Institution of Civil Engineers, with the object of eliciting the general expression of opinion relative to the principle.

The instruments in ordinary use, for ascertaining the pressure of the atmosphere, and for measuring the pressure of steam and other fluids, may be divided into three principal classes.

In the first class, the pressure is ascertained by measuring the height of the column of mercury which it is capable of sustaining, as in the common barometer, and the ordinary mercurial pressure gauge.

In the second, the pressure of the air, or other fluid, is ascertained by the amount of compression it is capable of producing, in a portion of air confined in a bent tube, or syphon, by a portion of mercury, or other liquid. The sympisometer and the short mercurial steam gauge are constructed on this principle.

The third class consists of a cylinder, in which a piston moves, being at the same time attached to a spring; Watt's indicator is so constructed, and it has also been proposed to employ it as a barometer, by exhausting the air from the interior.

The difficulty of obtaining an air-tight piston, sufficiently free from friction, appears to have led M. Conté, at the latter end of the last century, to propose the application of a shallow air-tight box, covered with a thin metallic diaphragm, from beneath which the air was exhausted. The diaphragm was supported by springs, contained within the box, so that the thin metallic diaphragm rose, or fell, with any variation in the pressure of the atmosphere.

The instrument known as the aneroid barometer,* is constructed in a somewhat similar manner, and the small motion of the diaphragm is multiplied by means of levers. A similar instrument was constructed by the Author in the year 1843, under the following circumstances. Having seen, in the French Exposition, a carriage, the springs of which were composed of thin lens-shaped metallic boxes, filled with compressed air, it occurred to him that a pressure gauge might be constructed on that principle; but on trying a series of experiments, by connecting the instrument with a steam boiler, it was found, that although at first it appeared to answer the purpose, yet after being used for a few weeks, or months, the metal cracked and the instrument became useless.

Sometime afterwards, the Author had occasion to construct a worm-pipe for a still, by bending a cylindrical tube into a spiral, or helical form. The workman performed the operation awkwardly,

* *Vide* Dent's Pamphlet descriptive of the Aneroid Barometer, page 15.

and partially flattened a considerable portion of the tube. In order to restore its form, one end was closed and the other was connected with a force pump, by which water was forced into the tube; as the flattened portion of the tube resumed its cylindrical form, it was observed that the spiral uncoiled itself to a certain extent, and it was immediately perceived that this action might be applied to the construction of a pressure gauge. Further experiments demonstrated the applicability of the principle to numerous uses, and the several forms of instruments shown in Plate 1, have been the result of subsequent experience.

Fig. 1 is a front view (showing also the sectional form) of a flattened metallic tube, bent into a circular form, and Fig. 2 is the side view. If a pressure of steam, or other fluid, be applied to the interior of this tube, it will be found to uncoil itself, as the pressure increases, until it assumes the form shown in Fig. 3, and on removing the pressure, it will return to its original form. If it is exposed to external pressure, or if the air is withdrawn from the interior, the tube coils itself up to a smaller diameter, as shown in Fig. 4. It will be found, that as the tube uncoils itself, it becomes thicker, from the sides becoming more convex, and as it coils itself up it becomes thinner. It is upon this relation, between the thickness of the tube and the diameter of the coil, that the action of the instrument depends.

If a flat band of metal is bent round into a circle, its transverse form remains unaltered, but if a semi-cylindrical, or gutter-shaped band, Fig. 5, is bent into a circular form, its convexity is diminished, and if the circle, to which it is bent, is of small diameter, the band will become almost flat in the transverse direction.

The same effect takes place, with a complete tube, as with the gutter-shaped band, and it is owing to this peculiarity, that tubular bodies possess such great rigidity. In fact, it is a law of general application, that a surface which is curved in two directions cannot have its curvature increased in one direction, without diminishing its curvature in the other direction, and *vice versa*. A tube may be considered as an assemblage of separate parallel filaments, or wires, as shown in Fig. 6. If such an assemblage of wires be bent into a curve, it will assume the form shown in Fig. 7, and the ends will no longer be square to the tube, as in Fig. 8, but will form angles to the radii of curvature, as in Fig. 9. The different parts of a tube, however, are not capable of sliding upon one another, like an assemblage of wires, but on the contrary, so mutually support each other, as to resist any attempt to bend the tube. If a curved gutter-shaped assemblage of wires is flattened out, it becomes round, or

convex at the ends, as in Fig. 10, from the central wires being longer than those at the sides, owing to their having originally formed a portion of a larger circle. If, on the other hand, the gutter be curved to a smaller diameter, the ends will become hollow instead of round. As these effects cannot take place in a gutter-shaped band, formed of one piece of metal, it becomes necessary for the different parts to accommodate themselves, in some other manner, to the varying curvature. This is effected by the change in the thickness of the tube, which allows the two sides to assume a greater degree of convexity in the transverse direction, in proportion to the diminution of their curvature in the longitudinal direction.

The converse of this proposition, equally holds good, that is to say, if pressure is applied to the interior of a curved tube of a flattened section, the effect is to separate the two sides of the tube, and thus to increase their convexity in the transverse direction. The consequence is the diminution of their curvature in the longitudinal direction.

From these considerations it follows, that a curved tube of cylindrical, or circular section, will not experience any change of curvature, when submitted to internal pressure, as the circle is the sectional form which all tubes tend to assume, when exposed to internal pressure. As the sectional form, therefore, cannot alter, the longitudinal curvature ought also to remain unchanged.

This theoretical observation is confirmed by actual experiment, the curved tube of circular section remaining unaltered in form, when submitted to internal pressure. The result is the same with external pressure, provided, of course, that the pressure is insufficient to totally collapse and destroy the tube.

The mutual dependence of the two curvatures on each other, is also proved in the following manner. When the flattened tube is embraced by a series of small clamps, as shown in Fig. 13, so as to prevent its sectional form from altering, on the application of internal pressure, its longitudinal curvature also remains unchanged.

Also, when the two ends of the tube are joined, so as to complete the circle, and pressure is applied, the tube, being unable to alter its longitudinal curvature, remains unaltered in thickness.

The variation in the thickness of a curved flattened tube, with the variations of its curvature, may be proved, by actual measurement, to be proportional to the change in its curvature, and *vice versa*; it may also be well shown by filling the tube with a liquid, and attaching a small glass cylinder to it, when every change of

[1851-52.]

c

curvature causes a corresponding motion in the liquid in the cylinder ; the capacity of the tube increasing as it is straightened, and diminishing as it is coiled up.

Again, if the external side of the tube be an arc of a radius of 60 parts, and the internal side be an arc of a radius of 50 parts, the thickness, or capacity of the tube would be 10 parts. If the thickness of the tube were then reduced to 8 parts, by approaching the two arcs together, without altering their curvatures, the external arc would necessarily be too long, and the internal arc too short, for their new positions, and the ends of the tube would be out of square, or be distorted. As, however, the metal resists this distortion, the tube accommodates itself to its new position, by increasing its curvature, so that the radii of the external and the internal arcs may still retain their former relative proportions. They therefore become 48 parts, and 40 parts respectively, and the arc of curvature is increased in the proportion of 4 to 5, whilst the thickness, or capacity of the tube is reduced in the proportion of 5 to 4. Thus, if the tube formed originally an arc of 60° , it will now form an arc of 75° .

The change in thickness of the tube, is thus proportional to the variation of its radius of curvature, and it is found, by experiment, that the motion of the extremities of the tube is proportional to the pressure applied, so that the indications are equal for equal increments of pressure.

This fact is of great practical importance, as the application of the principle to the construction of Pressure-Gauges, Barometers, and other instruments, is thereby greatly facilitated.

The simplest of these instruments, is the Steam-Pressure Gauge, Figs. 14, 15, and 16, in which rather more than one convolution of flattened tube, *A*, is employed ; one end of this tube is fixed to a stop-cock, *C*, in connection with the steam boiler, by the pipe, *B*, and the other end carries an index point, *d*, the extremity of which traverses a scale, *E*, graduated to a given pressure per square inch. In some cases there is a small slider, or an additional loose hand, *e*, which being pushed forward by the motion of the index, serves to register the maximum, or minimum pressure. Figs. 17 and 18 represent another form of Pressure Gauge, in which the tube, *A*, makes one turn, and is connected by a link, *e*, to the index, *d*.

These instruments answer perfectly for fixed engines, but if their position is varied, by laying them on their sides, the weight of the tube causes it to spring, and thus to interfere with the accuracy of the indications. In cases, therefore, in which the position of the instrument is exposed to variation, as in sea-going vessels, it is preferable to employ a circular tube fixed in the centre, to the stop-

cock, and having its ends connected by links, to the two ends of a lever turning upon a centre and carrying the index. The two branches of the tube are thus made to balance each other, and the index being also balanced, the instrument may be placed in any position, without its indications being in any degree affected. Figs. 19, 20, and 21, represent an instrument thus constructed and furnished with an illuminated scale, or dial.

When a great range of motion is required, the lever, instead of being placed on the axis of the index, carries a toothed segment, which drives a pinion on the spindle of the index, thus increasing the extent of indication. This arrangement, which is shown in Fig. 22, is well adapted for Barometers, in the construction of which, the air is exhausted from the flattened tube, before it is soldered up. The pressure of the atmosphere acts on the exterior, and is balanced by the elasticity of the tube, which varies in curvature, with every variation in the pressure of the atmosphere.

The manometers, above described, may be used as Vacuum Gauges, by continuing the scale below zero.

In some cases, and especially where the Manometers are liable to be exposed to frost, it is advisable to prevent the entrance of water into the flattened tube; this is effected, by interposing, in the pipe which leads to it, a flat box containing a diaphragm of vulcanized India-rubber. The flattened tube, and the space between it and the diaphragm, are filled with alcohol, or other liquid not liable to be congealed by cold, and the flattened tube is thus protected from injury. This arrangement is shown in Fig. 23.

If the curved flattened tube be filled with alcohol, or other liquid, and hermetically closed, the instrument becomes a Thermometer, showing by the motion of the index, every change in the volume of the inclosed liquid. The tube being formed of metal, has the advantage of transmitting the heat to the inclosed liquid, with greater rapidity than is the case with a glass thermometer. In some cases, however, as in ascertaining the temperature of corrosive liquids, it might be advisable to employ a tube of glass.

A Pyrometer, for measuring high temperatures, is made by connecting one of the pressure gauges by a small platinum tube, to a hollow ball of platinum filled with air. The platinum ball being exposed to heat, the elasticity of the air contained in it is increased, and the pressure is indicated by the gauge.

If instead of bending the flattened tube, it is twisted, by fixing one end and turning the other round, a sort of quick threaded screw is obtained, which has the property of untwisting itself, when acted on by internal pressure, and *vice versâ*. The action of the twisted

tube depends upon the same law, which has already been enunciated, namely, that a surface which is curved in two directions, cannot have its curvature increased in one direction, without diminishing its curvature in the other direction.

In fact, if any portion of the surface of the twisted tube be examined, it will be found to be curved in two directions, but instead of the two curvatures being at right angles to one another, they form an angle more, or less acute. Figs. 24 and 25 represent an instrument of this construction.

The motion of the twisted tube is indicated by a hand fixed to its extremity, or the motion is increased by means of gearing, or levers.

A thermometer made by filling one of these twisted tubes with alcohol, or other liquid, and provided with a float, is convenient for enabling brewers and others to ascertain the temperature of large quantities of liquid. The thermometer is allowed to float in the liquid, and the temperature can be read from the dial, without the necessity of lifting the instrument out of the liquid.

It would be tedious to mention all the modifications of which these instruments are susceptible; a few, however, may be alluded to as illustrating the others.

By employing a tube of suitable dimensions, in connection with a steam boiler, it may be made to open and shut the damper, and thus to regulate the pressure in the boiler. By a similar arrangement, a thermometer may be made to regulate an Arnott's stove, or a furnace.

In the steam-engine Indicators on this principle, Figs. 26, 27, and 28, a bent and flattened tube is substituted for the cylinder, piston, and spring of the ordinary indicator. One end of the bent tube is connected with the cylinder of the steam engine by a pipe, *B*, and the other end of the tube is attached by a short link to the middle of a long and light lever, *g g*, turning upon a pin, *f*, at its lower end. The pencil, *i*, is fixed to the upper end of the lever, and works across the paper, *H*, which is fixed on a vertical brass plate. This brass plate is moved up and down by means of a rack, *k*, and pinion, *l*. The pinion is driven by a pulley, *p*, fixed on its axis, and containing a flat circular box, in which is a spiral spring. A cord is fixed to, and wound several times round a pulley and is then attached to the cross-head, or to the beam, or parallel motion of the steam-engine; being always kept tight by the spiral spring. As the pencil moves in a small arc of a circle, whose radius is the long lever, it is necessary to measure the diagram with a scale of the same curvature. This instrument is extremely simple, and very effective.

Fig. 8.

11.

Fig 12.

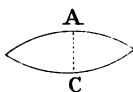


Fig 13.



Fig. 26.

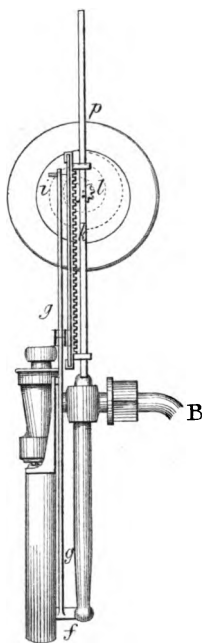


Fig. 28.

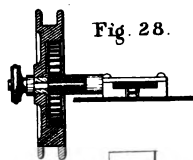
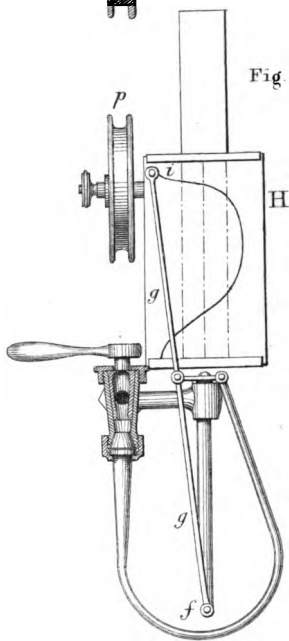


Fig 27.



The Author has also constructed a small experimental steam-engine, in which a bent and flattened steel tube is substituted for the ordinary piston and cylinder. One end of the bent tube is fixed to the framing, and provided with a slide valve; the other end of the tube is connected by a rod to the crank, and is supported by a lever, of such proportions as to agree in its motion with that of the free end of the bent tube. The slide valve is worked by an eccentric on the crank shaft. The bent tube is filled with oil, or water, so that the steam only enters the fixed vertical part of the tube, to an extent equal to the difference in the capacities of the tube in different positions. The loss of steam in filling the whole of the tube at each stroke is thus avoided. This engine has been driven at a very high velocity, without injury, which appears to be owing to the elasticity of the tube, forming a sort of cushion at each end of the stroke, and thus assisting in reversing the motion. This form of engine could not be expected to be generally adopted, in fact it was rather intended as an exemplification of the principle, than as a machine for common use; where, however, a small power, at a high velocity, is required, its freedom from friction might perhaps recommend it.

After many years' patient investigation of the subject, the Author has had the satisfaction of finding the correctness of the principle generally admitted, and his labours have been rewarded by a Gold Medal, at the French Exposition of 1849; and also by the Council Medal, at the Great Exhibition, in Hyde Park, in 1851. The French Government, upon the report of a special Commission, appointed to examine the instruments, has recently ordered, that one of the Pressure Gauges shall be provided for each of the Departmental Engineers engaged in the inspection of steam-engines, for the purpose of enabling them to verify the accuracy of all other descriptions of manometers, or pressure gauges, employed in Manufactories, or on Locomotive Engines, and on board Steam Vessels. These pressure gauges are also directed to be employed, according to the law, in proving boilers, by hydraulic pressure, equal to three times their ordinary working pressure, and for this purpose the French Government has ordered the Author to furnish a hundred standard manometers.

The principle developed in these instruments is brought forward with confidence in its correctness, and in the hope that the attention of the Members of the Institution being directed to the subject, further applications of practical utility may be devised.

The paper is illustrated by a series of diagrams, showing the various applications of the principle, and from them Plate 1 has been compiled.

Mr. BRUNEL, *V. P.*, said he had tried these instruments on the Great Western Railway, and had every reason to be satisfied with their accuracy, both as Manometers, and as Pressure Gauges, and he was of opinion, that the principle might be advantageously extended to other indicating instruments. The Barometer was not only a very ingenious instrument, but it was very correct in its indications; its sensibility was remarkable, for in merely going upstairs in any house, a variation would be observed, and in travelling along a railway, every elevation, or depression was correctly indicated to within 10 feet of the actual level. He had compared one of Bourdon's instruments, with a very accurate barometer made by Troughton, and after the necessary allowance for the constant deviation, he found a remarkable coincidence in the mean of the indications, extending over a considerable period.

In applying these instruments to steam-boilers, it would be advisable to isolate them by some good non-conductor, as the heat should be kept as much as possible from them.

Mr. Bourdon had omitted to state in the paper, that the variation in the barometer, occasioned by change in position, was remedied by a small bulb counterpoise, and since this addition, the instrument might be considered almost perfect.

In answer to a question from Mr. Gordon, Mr. Brunel said, that the principle had not hitherto been used in making instruments for deep-sea sounding, but there was every appearance of its being applicable for such purposes.

Sir E. BELCHER said the invention of a good instrument for deep-sea sounding, would be a great benefit, as not even Ericsson's could be entirely relied upon. The principle of Bourdon's instruments appeared to be simple, and easily adaptable to sounding instruments.

Mr. SIMPSON, *V. P.*, had used these instruments for pressures equal to a column of water of 350 feet, and for steam, up to 40 lbs. or 50 lbs. per square inch, and had found them indicate very accurately; indeed he thought they were likely eventually to supersede the ordinary pressure gauges.

Mr. POLE stated, that having been requested, during the discussion, to try an experiment with the instrument as made by M. Bourdon, in the form of a barometer, he could fully confirm Mr. Brunel's statement as to its sensitiveness. He had placed it first upon the basement floor of the Institution building, and had afterwards taken it up to the second floor. The difference in the indication of the instrument at these two levels, was very decided, amounting to two of the large divisions on the dial plate, each of which corresponded in value

to $\frac{1}{8}$ th of an inch fall of the mercury in an ordinary barometer tube. The total fall was therefore equal to $\frac{2}{8}$ ths of an inch (equal to 0.0416 inch;) and as the height of the second floor above the basement, was found by actual measurement to be 35 feet, this agreed very well with the ordinary rule, namely that $\frac{1}{8}$ th of an inch fall, corresponded to about 85 to 90 feet difference of altitude, according to the conditions of the atmosphere at the time.

No. 861.—“Description of the Prismatic Clinometer; a new pocket instrument for measuring Vertical Angles.” By WILLIAM POLE, Assoc. Inst. C. E.

IN the course of various investigations of a topographical nature, particularly in hilly countries, the Author has often found the want of some simple contrivance for measuring, with tolerable accuracy, angles of elevation above, or depression below, the horizontal line; it being necessary, at the same time, that the instrument should be sufficiently light and portable for the pocket; simple and convenient in use; and not liable to injury, or derangement in carriage.

Hitherto no instrument appears to have been contrived for fulfilling all these conditions. The Theodolite and the Altitude and Azimuth instrument, are, of course, out of the question for this purpose, as their size, their delicacy, and the necessity of carrying a stand with them, deprive them of the indispensable qualification of portability; besides which, the accuracy obtainable by such large instruments is not required in those observations wherein a portable instrument would prove most useful.

The Sextant (perhaps the most valuable angular instrument that has ever been contrived) has the power of taking angles in any plane, vertical as well as horizontal; and at sea, as is well known, the measurement of altitudes, or angles of elevation, is the principal use to which this instrument is applied. But on shore, where no sea horizon can be obtained, the sextant fails in this application, unless it is accompanied with another instrument, the Artificial Horizon, the management of which is, however, so troublesome, that it is seldom, or never employed for any other purpose than astronomical observations. Moreover, the use of the sextant in conjunction with the artificial horizon, is limited to angles of elevation; it will not show a level line, nor measure angles of depression; perhaps as frequently wanted as those of elevation. For example, an observer standing on a hill might wish to find its height by taking the angle of depression of some object in the plain, or valley below: this, with

the sextant and horizon, it would be impossible to do. And it would be equally impossible, with these instruments, to find a contour, or level line in a valley; an operation which, if it could be readily done, even approximately, would often be of great assistance, in determining the general levels of a tract of ground.

Some years ago, Sir John Macneill made an effort to dispense with the use of the artificial horizon, by attaching a small spirit bubble to the sextant,* which gave the power of holding the instrument in a certain definite position, with regard to the horizontal, and thereby determining the required vertical angles. The Author, at one time used a sextant constructed in this manner; but it was very awkward to manage, dangerous to carry, and the application of the bubble to the smallest, or box form, of sextant appeared to involve considerable difficulties of construction and use.

Another, and a very old contrivance for measuring vertical angles roughly, is the Plummet instrument; in which two sights, attached to a divided arc of a circle, are pointed to the object, while the line of a plummet hanging from the centre, cuts, upon the divisions, the angle subtended with the horizontal. This contrivance has been adopted by Professor Sedgwick, in an instrument for ascertaining the dip of strata; and several other well-known applications of it might be mentioned. All these, however, have the inconvenience of requiring to be carefully steadied against some fixed object, during the observation, as otherwise the position is liable to waver, while the eye is removed from the sights, to look at the plummet, and thus the reading may prove untrue. Moreover, this kind of instrument has another great imperfection, which considerably limits its use, namely, that it is inapplicable in windy weather: even a slight breeze will render the plummet unsteady; and all who have worked much out-of-doors, know well how seldom a perfectly calm atmosphere can be depended on. If, to remedy the evil, the plummet be enclosed in a case, it must become so short as to lose, in a great degree, its sensitiveness and accuracy.†

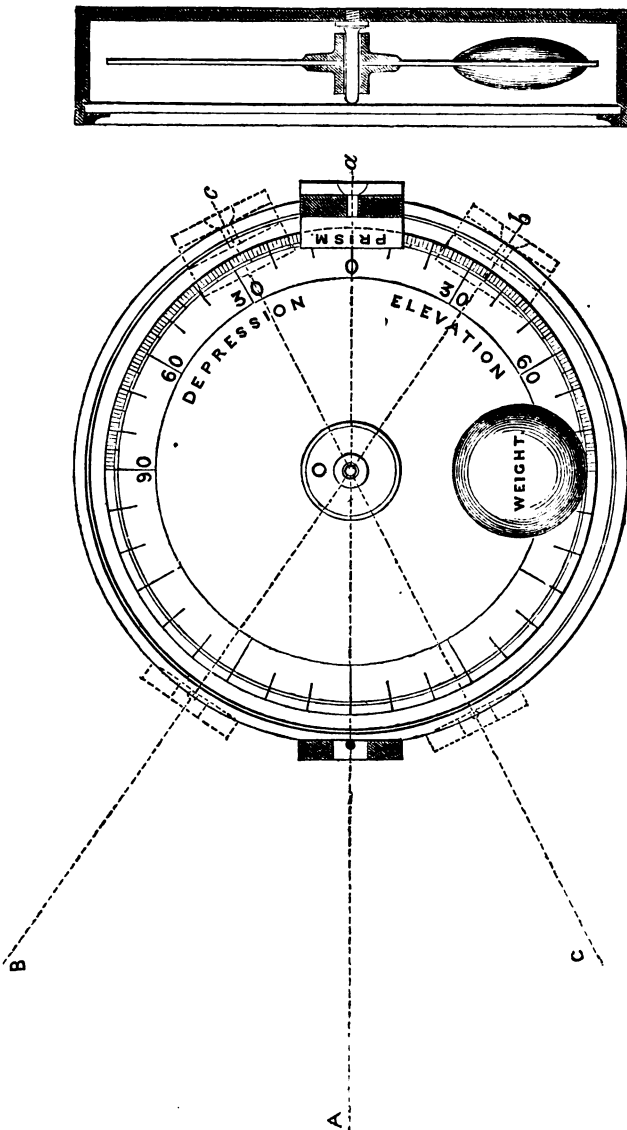
The instrument contrived by the Author, has, he conceives, advantages over all those above mentioned. It is an application, to the measurement of vertical angles, of the elegant contrivance of Captain Kater, known by the name of the Prismatic Azimuth Compass. The peculiarity of this instrument (now so extensively used both for marine and land surveying) consists in a prism, placed in the line of

* This contrivance is noticed in Mr. F. W. Simms' Treatise on Mathematical Instruments, 8vo., page 57. London, 1836.

† Vide also Grantham's Clinometer; Minutes of Proceedings Inst. C. E., vol. v. page 480.

two sights, and directly over the divided edge of the compass card, by means of which, while the observer directs the sights to the object in the distance, he sees, reflected at the same time in the prism, the reading of the azimuth on the card below.

Fig. 1.



The adaptation of this to the measurement of vertical angles is very simple. The compass card is removed, and another card substituted without a needle, and so hung on the centre pin, as to turn freely when held in a vertical position. The card is divided on the edge into degrees, &c., and a weight is attached to one side, which has the effect of always keeping that part of the card vertically under the centre pin. Fig. 1 will explain the construction of the new instrument without further description.

Now if the zero point of the divisions is so arranged, that the line joining it and the centre, is perfectly horizontal, when the card hangs freely, it follows that by bringing the prism to read *zero* on the divisions, the sights will be set in a perfectly level line aA , and will therefore determine a point, A , in the distance, level with the eye of the observer, in the same manner as an ordinary telescope level.

Suppose then the sights to be directed to some elevated object B . If the card be allowed to hang freely, the weight will keep it (notwithstanding the motion of the sights and the outer case) in the same position as before, viz., with the zero line horizontal, and therefore the prism will read an angle aOb , which is evidently the same as that AOb , namely, the altitude, or angle of elevation of the object B , above the horizontal. Similarly, by directing the sights to a low object C , the prism will read the angle aOc , or the angle of depression of the object below the horizon.

The advantages of this instrument will be evident.

1st. It is very portable. A good instrument of the kind can be made about 3 inches diameter, and $\frac{3}{4}$ inch deep; a size that can be put in the waistcoat pocket if required.

2nd. It is simple, durable, and free from risk in carriage, containing no spirit bubbles, or any other delicate parts, at all liable to be broken, or to get out of order.

3rd. It is very convenient and easy in use; it requires no stand, nor does it even need steadying against any fixed body, as the eye reads the angle at the same time that it is directed to the object in the distance. It may be used in any weather, as the whole of the moving parts are enclosed.

4th. It is capable of a considerable degree of accuracy, if carefully made. Of course it is not pretended, that a diminutive apparatus of this kind, can compete in delicacy of measurement with the larger and more perfect instruments; and in cases where great accuracy is required, there is no alternative but to resort to these; but for approximate results the present contrivance may be safely relied on. The card of an instrument 3 inches in diameter may be

divided to 20 minutes, and as the prism magnifies considerably, each of these spaces may be again subdivided into several parts by the eye. In this way an approximation might be obtained to within 1 foot of height at about 500 feet distance, a degree of accuracy more than sufficient for all the purposes which an instrument of this kind is intended to serve.

It is unnecessary to do more, than allude, in a few words, to the practical applications of the instrument. Such desiderata as the slope of a hill, or a bank; the inclination of a road; the dip of strata; or the determination of a contour, or level line; may be obtained by simple observation, the reading of the angle being all that is necessary for these purposes. For the determination of heights, a simple trigonometrical computation is requisite;* and the distance of the object from the observer must also be ascertained, either by measurement, or by some of the many simple contrivances familiar to surveyors.

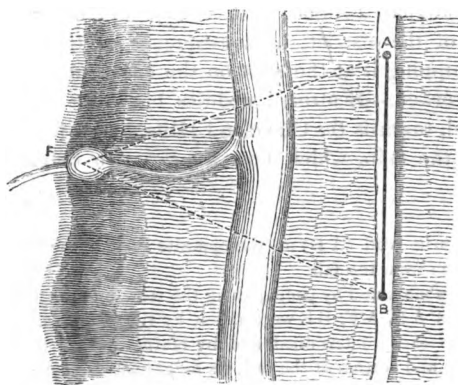
* If the angle is small, the use of logarithms is not necessary, as the arc may be assumed to coincide with its tangent and sine. In this case let θ = vertical angle (expressed in degrees) D = distance; and H = height. Then

$$H = \frac{D \theta}{57.3}$$

If the angle is so large, that the above assumption will produce important errors, the usual formula ($h = d \tan \theta$) must be employed.

When the vertical angle instrument is combined with the Prismatic Compass (as hereafter described) both the heights and the distances of inaccessible objects may be determined together. The following example (Fig. 2) will show how simple, with these means, the operation becomes.

Fig. 2.



It was required to determine the height of the Staubbach Waterfall (F), the

In the above account of the vertical angle measurer, it has been described as a separate instrument; but it may easily be combined with the Prismatic Compass, by so constructing the centre pin, that it will serve to carry either the compass card, or the weighted one; the same box, sights, and prism, serving for either instrument, as may be required. By opening the glass cover, either of the cards may be hung on the pin, the one out of use being kept in a small detached box.

The Author has used an adaptation of this kind (made under his direction by Messrs. Troughton and Simms) during a late journey in a mountainous country, and has found it exceedingly convenient and useful. Indeed a traveller provided with this compound instrument, and having a little practice in measuring distances by pacing, is enabled to make a rapid survey of a tract of ground, with the great advantage of adding contours and heights, as well as laying down the topographical features of the plan.

The communication is illustrated by models and diagrams of the instrument, and of its application, from which Figs. 1 and 2 have been compiled.

IRON-ORE NEAR MIDDLESBRO'-ON-TEES.

Mr. C. MAY directed the attention of the Meeting to some samples of iron, made from iron-ore raised in the neighbourhood of Middlesbro'-on-Tees, of which specimens were exhibited.

Iron-ore had been found and worked in the district for upwards of fifty years, but the discovery of this extensive mineral bed was due to Mr. J. Vaughan (Assoc. Inst. C.E.), and arose from a close examination of the district, in consequence of the difficulty experienced in shipping it at the spot on the coast, near Redcar, where it was first worked.—Scattered nodules had been previously found further inland, towards the Cleveland Hills, and a few trials sufficed to lay open the vein, which now appeared to extend throughout

observer being on a road (A B) on the opposite side of the valley, and at an unknown distance from the fall.

A line A B was measured by pacing along the road, and the magnetic bearings of the three lines A B, A F, B F were taken by the compass. From this, the distance A F was easily determined, and by taking from A the angles of elevation of the top and bottom of the fall, its height was immediately ascertained. The whole of the observations did not occupy many minutes, and the calculations required only about 30 figures.

many thousand acres. It belonged to the oolitic strata, and consisted of carbonate and peroxide of iron with alumina and silica, laying in a seam of an average thickness of about 14 feet, at an angle of inclination to the south, of about $1\frac{1}{2}$ inch in the yard, and at, in some places, only about 4 feet from the surface. The average yield, in the blast furnace, was about 33 per cent., producing an excellent quality of metal for castings, as well as for rails, boiler-plate and merchant bars. Up to the present time only about 250,000 tons per annum of the iron-ore had been raised, but as its quality and the facility of obtaining it became more generally known, there could be no doubt of its being much more extensively employed; already the proprietors of a large work had ceased working their former mines and conveyed this ore a distance of fifty-five miles by railway, with advantage to the quantity and quality of the iron made, and in the cost of production.

There was little doubt of this discovery producing nearly as great a revolution in the manufacture of iron in Yorkshire, as had resulted from the employment of the "Black Band" ore in Scotland.

The following analyses supplied by Mr. Boyd, were interesting in a chemical point of view. Mr. May believed that the items "moisture and loss," included some phosphoric salts:—

ANALYSIS OF IRON STONE AT ESTON, IN CLEVELAND.

Top Layer.

Silica	15.20
Alumina	7.60
Carbonate of lime	2.60
Carbonate of magnesia	0.12
Peroxide of iron	35.58
Carbonate of iron	36.90
Moisture and loss	2.00
	100.00

Metallic iron 42.7.

Hard Grey Layer.

Silica	9.60
Alumina	7.20
Carbonate of lime	4.60
Carbonate of iron	52.93
Peroxide of iron	23.47
Moisture and loss	2.20
	100.00

Metallic iron 42.0.

Bottom Layer.

Silica	10·60
Alumina	5·00
Carbonate of iron	31·27
Peroxide of iron	51·13
Moisture and loss	2·00

 100·00

Metallic iron 50·88.

Crust which adheres to all these layers, until exposed to the air:—

Silica	10·40
Alumina	7·60
Carbonate of iron	39·54
Peroxide of iron	40·46
Moisture and loss	2·00

 100·00

Metallic iron 47·4.

Top lost in roasting	16·4 per cent.
Hard grey do.	22·8 do.
Bottom do.	18·0 do.
Crust do.	17·0 do.

November 25, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

No. 862.—“ On the application of Machinery to the manufacture of Rotating Chambered-Breech Fire-Arms, and the peculiarities of those Arms.”* By COLONEL SAMUEL COLT (U. S. America), Assoc. Inst. C. E.†

AMONG the various departments of practical science, there is perhaps none in which more rapid advancement has been made within the present century, than in the manufacture of fire-arms, and great ingenuity has been displayed in devising improvements in them; but it is the extent to which machinery may be used in their construction, that must render the subject interesting to Engineers.

It is not the design of this paper, to enter upon a history of the first employment of fire-arms, nor yet to trace all the gradations of improvement that have taken place, since their introduction as

* The discussion upon this subject was extended over a portion of two evenings, but an abstract of the whole is given consecutively.

† The Author was subsequently elected Assoc. Inst. C. E. May 4, 1852.

weapons of war, such a subject being somewhat foreign to the scientific views, and peaceful occupations of Civil Engineers; but as experience has shown, that perfect weapons of defence are indispensable for the pioneers of civilization in new countries, and still as necessary for the preservation of peace in old countries, the best means of producing them by the aid of machinery, must be interesting; it is therefore intended, briefly to examine, chronologically, as far as recent researches extend, the gradual advances in the form and construction of fire-arms with magazines, or chambers, for repeated discharges, and to contrast them with the modern repeating chambered-breech arms introduced by the Author.

The principal collections of arms examined for this purpose are those in the Tower of London, the United Service Museum, the Rotunda at Woolwich, Warwick Castle, in England, and the Musée d'Artillerie, and the Hotel Cluny, at Paris; all these show that at all times and in all countries, the attention of armourers has been constantly directed to the subject, and much ingenuity has been displayed in the improvement of these engines of destruction, and as the use of gunpowder became better understood, and fire-arms were more generally employed, the desire to improve them increased, and their construction was materially changed. The chief progressive steps, after their first introduction, were, the hand-gun, the match-lock, the pyrites, or wheel-lock, the flint-lock, and the percussion lock.*

The Author had been aware since the year 1835, of the existence of ancient examples of repeating fire-arms, but it has only been on the occasion of his present visit to Europe in 1851, that he has been able to devote any attention to their chronological history, as exhibited in the specimens, existing in the museums, and private collections, to which he has recently obtained access. These specimens it is necessary to describe briefly, in order to render apparent the simplicity of design, the superiority of workmanship, the uniformity of construction by means of machinery, and the thorough efficiency of the repeating arms now submitted to the Institution.

* The first small fire-arms were called Hand Cannons and were fired from a rest, by the application of a match; when their weight was further reduced and a match-lock was added, they were called Calivers. In a short time they were mounted on a stock, rendered more portable, and termed Arquebuse; the shorter arms of this kind being called Petronel, or Poittrinal, from their being fired from the shoulder, without a rest. The German Reiters introduced the Pistol, named from Pistoia, in Etruria, a place celebrated for the manufacture of that species of arms. The introduction of the Musket, the Rifle, and the various modifications of them, has been very gradual, but has been accelerated latterly, by the general determination to give long-range arms to the troops.

The earliest specimen, which the Author has been enabled to discover, is a match-lock gun now in the Armoury of the Tower of London, supposed to be of the fifteenth century, (Fig. 1, Plate 2.) It has a revolving breech with four chambers, mounted on an arbor parallel with, and welded to the barrel. The hinder end of the arbor is attached to the gunstock, by a transverse pin, or nail. Notches are made in a flange, at the fore end of the breech, to receive the end of a spring, fixed to the stock, and extending across the breech, for the purpose of locking it, when a chamber is brought up into a line with the barrel. The antiquity of this arm is evident, from the match-lock contrivance for igniting the charge, and the fittings, and mounting indicate an Eastern origin. Each charge chamber is provided with a priming pan, with a swing cover, which, before firing, would require to be pushed aside by the finger, to present the priming powder to the match. A repetition of the fire is effected by throwing back the match-holder, and turning the breech by hand, to bring up another loaded chamber.

In the collection at the Musée d'Artillerie, at Paris, there are two specimens of match-lock guns, with revolving breeches, both of them being very similar to that which has been described; these have each eight chambers rotating by hand, and the covers of the priming magazines require to be pushed back by the finger before firing.

The next match-lock arm (Fig. 2, Plate 2,) was found, by the Author, in the possession of Messrs. Forsyth and Co., who obtained it, about twenty-four years ago, from the late Lord William Bentinck, the Governor-General of India, whence it was brought, with other curious weapons. The construction of this arm closely resembles that shown in Fig. 1, just described; but the workmanship is superior, and it is more elaborately ornamented. The breech, which requires to be moved by hand, has five chambers, each having a priming pan with a swing cover. The arbor is attached to the barrel, which, at the end adjoining the breech, is enlarged to correspond with the diameter of the revolving chamber, to which it forms a kind of shield.

But in order to mitigate the danger, which was, no doubt, apprehended, from the simultaneous discharge of all the chambers, by the spreading of the fire, from the exploding chamber, which would be the inevitable effect of this shield, the maker has provided vents for the charges, by boring holes through the enlargement of the barrel, corresponding to the charge chambers in the revolving breech. In one respect this gun gives evidence of progress, inasmuch as the breech-arbor is more firmly secured to the stock by two square pins, thus ensuring a firmer connexion between the

parts. The method of locking the breech is similar to that of the first arm described (Fig. 1), except, that the spring for securing the breech is fastened to the barrel instead of to the stock. The thinness of the metal of the barrels and the extreme length of the revolving chambers, in both these specimens of arms, would seem to indicate the bad quality of the gunpowder used at the period of the irconstruction.

The third specimen is a decided advance on the preceding guns. This arm (Fig. 3, Plate 2), which was found in the Armoury at the Tower, is furnished with a Pyrites wheel lock, and one priming pan is common to all the six chambers of the revolving breech; this pan is fitted with a sliding cover, and is so arranged that the serrated edge of a vertical wheel may project into it, amongst the loose powder in the pan; to this wheel a rapid rotary motion is given, by means of a trigger spring, acting upon a link lever, attached to the arbor of the wheel, the teeth of which, striking upon the pyrites, create the sparks which ignite the priming powder. The fire is then communicated laterally to a train of powder about $2\frac{1}{2}$ inches long, before it reaches the charge in the breech, and which train of powder and priming require to be renewed, each time, before the charge in the adjoining chambers can be exploded. A stop-pin is made to enter the orifices in the wheel, to stay its action, until the proper time, and on pulling the trigger the firing is effected.

In this instance, also, the breech is rotated by hand, and the barrel and breech are brought into contact, by a nut working upon the threaded end of the breech arbor. By the employment of one priming pan for all the chambers, and from the apparent necessity for closing the rear end of the breech with a cap, so as to leave but one small opening for the passage of the fire, from the priming-pan to the breech, the liability of the several chambers to be simultaneously fired was greatly increased; for the cap, which covers the rear end of the breech, prevents the escape of the fire laterally, and forms, in fact, a channel for guiding the deflected fire to the touch-holes of all the charges. This gun has no stock in front of the breech; but, unlike the previous specimens, the barrel is cut away on each side, so as to allow the balls to escape, in case of premature explosion. A pistol of nearly identical construction (Fig. 4, Plate 2) is in the collection at the Rotunda, at Woolwich.

In the Hotel Cluny at Paris, there is an arm of the 17th century, with a pyrites lock, and eight chambers, very similar in general construction to that found in the Tower, but differing materially in the arrangement of the touch-holes. There is one main

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priming tube, extending from the pan to the rear of the revolving chambers, with eight corresponding tubes, extending from the rear, to within a short distance of the front end, where an orifice is pierced into each chamber, for the purpose of igniting the charge immediately behind the bullet; thus obliging the charge to burn backwards, towards the breech. This arrangement, which was evidently made for the purpose of preventing the simultaneous explosion of the charges, has produced a construction of arm, almost identical with that of the modern Prussian needle gun, for which the great feature of the more rapid ignition of the whole of the charge of powder has been claimed. The priming-tube, and the pan, as in the arm at the Tower, require to be filled with gunpowder every time a chamber is discharged.

Fig. 5, Plate 2, represents an elaborately finished Spanish gun of a more recent date, with a flint lock. The breech is rotated by hand, and it is locked in the proper position for firing, by a pin, which enters a hole in the rear end of the breech, and which has to be drawn back, prior to bringing up a fresh chamber in a line with the barrel. The chief peculiarity of this gun is, that a magazine of priming powder is provided, immediately above a fixed priming pan, which serves for the four chambers of the breech. The magazine is hinged to the pan and is fitted with a sliding bottom, which when drawn out, is intended to allow a certain amount of powder to fall into the pan, and when pushed back cuts off the supply. The rear surface of this magazine serves also as the steel, or striking surface for the hammer, and it is ribbed on its face to receive the blow of the descending flint. The fore end of the breech is closed in by a filling piece of wood, attached to the barrel, and the hinder end is enclosed in a cap, as in the last example. This arm is therefore like the others fatally defective, the priming powder in the magazine would inevitably explode; the priming fire would be conducted to all the other touch-holes, and the lateral fire, at the other end of the breech, would be directed into the several chambers, and explode all the charges prematurely.

In the Armoury at Warwick Castle there is a gun which appears to be an attempt to insure greater safety in firing, but at the expense of greater complexity of mechanism. It has a flint lock and a breech with four chambers, to be rotated by hand; each chamber is furnished with a priming-pan, and a steel, which latter forms also the cover. The firing of one charge is not, therefore, so liable to ignite the powder in the other chambers. The stock in front of the breech is very thin, so as not to cover the other three chambers; consequently,

if a premature explosion took place, no material injury could occur to the arm. The chambers would appear to have been fastened by a spring from the end of the barrel.

An arm very similar in construction to the last was found in the Tower of London (Fig. 6, Plate 2). The breech is composed of four distinct tubes, or chambers, attached together by two end plates. Each tube, or chamber, is provided with a priming-pan and steel, and the breech is rotated by hand. It is retained in the required position for firing, by a bolt acting upon the rear end, which is withdrawn, by hand, when the breech is required to be moved round on its arbor.

The specimen (Fig. 7, Plate 2), which appears from its construction, to come next in order of date, was obtained by the Author from Messrs. Forsyth and Co.; it bears the evidence of English construction, as on the lock is inscribed "John Dafte, London," in characters which indicate that it is scarcely more than a century old; it may, however, be a copy of an older arm. There is evidently an attempt, in this arm, to produce a more compact weapon, for instead of having a projecting pan and steel for each chamber, recesses are made in the periphery of the breech, to form pans, and one steel was probably provided to stand over the breech, attached to the barrel. The breech, containing six chambers, is rotated by hand, and is locked when in position for firing, in the same manner as in Fig. 3; priming powder is also placed in a pan for each chamber, whilst the weapon is being loaded; these priming pans are each covered by a sliding plate working in parallel guides affixed to the periphery of the breech, with the intention of protecting, in a more perfect manner, the priming of the adjoining chambers, and thus preventing premature explosion. Connected with the hammer, is a small bar which projects forward, so that when the trigger is pulled, the hammer, in its descent against the steel, brings the small bar into contact with a projection on the cover of the upper priming pan, pushing it forward, and exposing the powder in the pan to the action of the sparks struck from the flint of the hammer. This arrangement has the advantage of compactness, and in this particular it may be considered a mechanical improvement on its predecessors; the stock does not reach beyond the base of the breech, and the barrel is cut out in front of the chambers, to allow the balls to escape, in case of premature explosion. This arm bears evidence of being radically defective; for in consequence of the holder of the steel being fastened over one of the chambers, into which the fire would be deflected, premature explosion necessarily followed, the

steel was broken off and the arm was probably rendered useless by the first discharge.

In the collection at the United Service Museum, London, is a brass model pistol, with six chambers, said to have been constructed in the time of Charles the First. This specimen displays more ingenuity and greater skill, in its design, than any of the early weapons hitherto discovered; but it is, evidently, only a model of a proposed construction, and has never been practically tested, as if it had been used, it would have been blown to pieces by the first discharge. In its general design it greatly resembles the arm last described; each chamber being provided with a similar priming pan and sliding plate to cover it, and attached to the hammer is a bar, for pushing back the cover, and exposing the powder to the fire from the flint. A steel, for the flint to strike on, is jointed to the barrel, in the same place and in the same manner as in the arm, Fig. 7, Plate 2, and is consequently open to the same objections. The arbor, on which the breech turns, is screwed into the barrel and is attached to the stock by a pin passing through it. From this description, it will be understood, that the model under consideration is tolerably free from the defects previously pointed out; but inasmuch as it possesses no means of regulating the contact of the breech and the barrel, so as to prevent the spread of lateral fire, it, like all the preceding specimens, offers no security against the simultaneous discharge of all the chambers.

It is not a little surprising, that the next example of a rotating chambered-breech gun, with a flint lock, Fig. 8, Plate 2, patented by Elisha H. Collier (U. S. America), in 1818, should exhibit nearly all the serious defects which had doubtless been discovered, and had been, to some extent, remedied by the earlier makers. The objectionable parts of this arm are the priming magazine, the flue which would conduct the fire round to the different touch-holes, and the cap in front, which would direct the lateral fire into the adjoining chambers. The breech is made to bear against the barrel, by means of a coiled spring, which would probably be efficient while the gun was clean, and each chamber is recessed to receive the abutting end of the barrel, with the intention of effecting a closer junction. This bearing up of the chambered-breech against the barrel is maintained, during the firing, by a bolt which is thrust forward by a cam on the spindle of the hammer, when the trigger is pulled, and would be effective for a few discharges, until the junction between the cylinder and the barrel, or the arbor on which the cylinder turns, became foul. The valve, which forms the bottom of the priming magazine, is

self-acting and supplies a certain quantity of powder to the pan, when the magazine (which forms at the same time the cover of the pan, and the steel for the hammer to strike upon), is brought into its elevated position. In order to rotate the breech, the hammer is thrown back to half-cock, the breech is then drawn out of contact with the barrel, and another chamber may be turned up by hand into a line with it.

The arrangement of the flint-lock chambered-breech fire-arm, contrived by Wheeler of Boston, and patented by Cornelius Coolidge, in August, 1819,* differs from the arm patented by E. H. Collier (in whose patents Coolidge was interested), in having fastened to the chamber, and to the arbor, a coiled, or spiral spring, which being wound up, is intended to constitute a power for assisting in causing the cylinder chambers to rotate, as by a complicated arrangement in the lock, an escapement motion was effected by the action of the lock itself. This arm possesses all the complication, and the imperfections of the worst of the other arms, with the same liability to premature explosion, and these defects have been admitted, inasmuch as E. H. Collier acknowledged that "in manufacturing these arms he improved the gun as he went on, and left out the spring because he thought it was useless;"—"he wanted to get rid of all superfluous parts, and left the spring out, because he considered the gun was better without it;" thus leaving the chambered-breech to be rotated by hand.

During the latter part of the last century many ingenious persons directed their attention to the improvement of fire-arms, with a view to simplify their construction, to render them more effective, and to combine safety with celerity in firing.

Among some of the most important of these improvements, may be mentioned, the peculiarly-constructed breech, patented by Mr. Henry Nock, in 1787, and the application of fulminating powder for igniting the charge in the chamber of the barrel, for which the Rev. Mr. Forsyth obtained a patent in 1807; the principal objects of this latter invention were to supersede the flint lock, and to obtain the rapid and complete combustion of the whole charge in the barrel, so as to obviate the loss of force which formerly resulted from the escape of air through the touch-hole. Many ingenious contrivances have since been introduced by the manufacturers of

* Vide "Description des Machines et Procédés spécifiés dans les Brevets, d'invention, de perfectionnement et d'importatio ." Tome xi, page 42. Paris, 1825.

fire-arms, of different countries, for simplifying the mechanical arrangement for firing by percussion, the adoption of which has now become general.

These improvements advanced fire-arms towards perfection ; but still they laboured under great disadvantages, chiefly from the waste of time in reloading, which prevented the full extent of the rapidity of discharge, that an ordinary gun constructed of iron and steel could endure, from being taken advantage of.

The Author, living in a country of most extensive frontier, still inhabited by hordes of aborigines, and knowing the insulated position of the enterprising pioneer, and his dependence, sometimes alone, on his personal ability to protect himself and family, had often meditated upon the inefficiency of the ordinary double-barrelled gun and pistol, both involving a loss of time in reloading, which was too frequently fatal, in the peculiar character of Indian border warfare.

By the United States' Government, also, it was considered an object of great importance, to obtain an effective repeating arm, as the peculiar characteristic of the mode of attack by the mounted Indians, was to overwhelm small bodies of American soldiers, by rushing down on them, in greatly superior numbers, after having drawn their fire, and then to despatch them, whilst in a comparatively defenceless state, from the necessity of reloading their arms.

After much reflection and repeated trials, he effected an arrangement in the construction of revolving fire-arms, without having seen, or being aware, at that period (1829) of any arm more effective than a double-barrelled gun having ever been constructed, and it was only during a visit to Europe, in the year 1835, that he discovered he was not the first person who had conceived the idea of repeating fire-arms, with a rotating chambered-breech.

The first arrangement, contrived by the Author, was the combination of a number of long barrels, to rotate upon a spindle, by the act of cocking the lock, and similar in construction to those now generally made ; but from the weight and bulk of the arm, it soon appeared better to have only a rotating cylinder containing several chambers, and to discharge through one barrel. For this he took out a patent in 1835, in which he claimed as peculiarly his own, the arrangement, or construction shown in Figs. 9 and 10.

Fig. 9, Plate 2, represents a pistol, exhibiting the mechanical combination of the arm at that early stage ; the hammer is hung at the fulcrum A : the key bolt, or catch lever which holds the cylinder, is hung at the fulcrum B. The lifter, to move the ratchet, has a

working connection with the hammer on the left side, at C. The arm, D, of the lifter, works into the teeth of the ratchet, on the left: E, represents the ratchet, when connected with the shackle. F, F, is the middle and forward part of the shackle, on which the ratchet is placed. G, is the arbor on which the cylinder revolves: the end H, is the nut that holds the arbor in its place, when in the shield: I, I, represent the forward end of the arbor, which passes through the plate, and the projection on the lower part of the barrel, and the barrel is secured to the arbor by a key at J. K, represents the fulcrum of the trigger: L, is the spring which forces the connecting rod against the end of the hammer: M, is the spring which forces the key that holds the cylinder: O, is the main spring. By drawing back the hammer, the pin P, operates upon the after end of the key-bolt, or catch-lever, that locks the cylinder and raises it, consequently, the other end R, is drawn from the cylinder, and the arm D, of the lifter begins to act on a tooth S, on the left side of the ratchet, which being connected with the cylinder, by means of the shackle, turns until the next chamber is brought opposite the barrel. When the pin P, is relieved from the key, by passing over its upper end T, the pin allows the end R, of the key, to be forced by means of the spring M, into the succeeding ward of the cylinder: at the same time, by the action of the lower end of the hammer U, upon the connecting rod V, a forward horizontal motion of the rod is produced, when the end W, is brought in contact with the upper projection of the trigger, and forces it down to a proper position for the finger, when the claw X, of the trigger, hooks into the connecting rod, which holds the hammer, when drawn back, or set, by means of the end V, entering the lower catch Y, on the hammer.

On pulling the trigger to discharge the pistol, the connecting rod is drawn from the catch of the hammer, when the main spring forces the hammer forward, the upper end striking the percussion cap; during which operation the lifter, by means of its lateral motion to the left, falls below a succeeding tooth on the ratchet: when by the lateral motion of the after end Q, of the key, which holds the cylinder, the pin P, of the hammer, is permitted again to fall below it. By repetitions of the same motion of the hammer, the same effect is produced until each succeeding chamber is brought round and is discharged.

Fig. 10, Plate 2, represents the principle of the invention as applicable to rifles and muskets. In order to set the lock, the fulcrum of the lever being at A, by drawing down the ring B, the end C, operates upon the rod D, of the hammer, whose fulcrum being at E,

throws back its end F, when the trigger at G, whose fulcrum is at H, operates upon the catches of the hammer, at I, to hold the lock when it is set. When the end F, of the hammer, is removed from the adopter, whose bearings are at J, J, it is drawn back by means of the coiled spring K, until its end L, is drawn back sufficiently to allow the cylinder to turn. After the finger is released from the lever, when the lock is set, a small spring draws it back to its former place, to make room for the end D, of the hammer, so that its force may not be impaired. By pulling the trigger from the catch of the hammer, the main spring, which is connected to the hammer by the stirrup O, forces its end F, forward against the end M, of the adopter, whose end L, is brought in contact with the percussion cap, placed upon the tube N, so as to explode the charge of powder. In loading the arm it is only requisite to draw the key J, which will liberate the barrel; then by drawing the key that locks the cylinder, which is effected by drawing back the hammer to half-cock, the cylinder may be taken from the arbor.

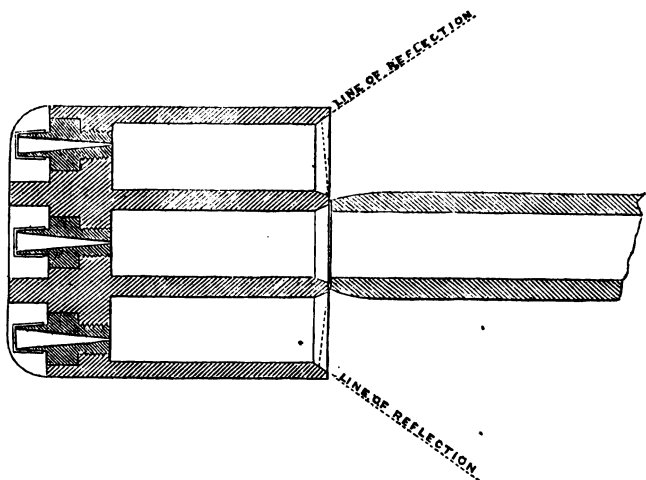
Fig. 11, Plate 2, represents a rifle made by the Author, in 1836, to rotate and fire by the continued action of the lever, or by the use of a trigger.

The arms so constructed, consisting of a large number of pieces, and assembled in a complicated manner, were soon found to possess many practical disadvantages, arising chiefly from the wish of the Author to construct compact and good-looking weapons. His original experiments had all been made on skeleton arms, solely with a view to utility, and in them there was not the liability to premature explosion, from the escape of fire at the mouth of the chamber, or by the inter-communication of the ignited detonating caps; but when he enclosed the rear, and the mouths of the rotating chambers, the fire, being confined beneath the shield and the cap, was communicated successively to the percussion caps, and in front was conveyed into the chambers, so that premature and simultaneous explosion of the charges necessarily took place.

In consequence of these premature explosions, it became necessary to remove the shield, from over the base of the chambers, and to introduce partitions, between the nipples, or cones, to prevent the fire from spreading to and exploding the adjoining caps; but this only partially accomplished the object. There still remained risk of explosion from the spreading of the fire laterally between the base of the barrel and the face of the chamber. To meet this danger, the metal plate which was attached to the barrel, and projected over the chambers, was removed; this obviated to a certain extent, but

did not altogether prevent, the simultaneous explosion of the charges; for during a trial of the arm, by order of the American Government* an accident occurred, from the simultaneous explosion of two chambers, which induced the Author, after much reflection, to give a slight chamfer, or bevil to the orifice of each chamber, so as to deflect, or throw off at an outward angle, the fire which expanded laterally across their mouths. The reason for this alteration was, that when the lateral fire met the rectangular edge of the orifice of the chambers, the angle of incidence being equal to the angle of reflection, the fire was conducted downwards, or inwards to the charge; but when the flame struck the chamfered edge, it was directed outwards away from the charge. This action is shown in Fig. 1, and unimportant as this alteration may appear, it has proved

Fig. 1.



so effectual, that if loose powder is placed over the charge, in the adjoining chambers, it is not now ignited when the pistol is discharged. These and other improvements have brought the fire-arm to its present safe and effective condition, and the Author believes, that no casualty can occur, nor that more than one charge can be fired at one time, if the metal is sound and the arm is properly loaded.

* Vide "Report of the Secretary of War, 25th Congress, First Session, June 1837."

The early arms of the Author were made from 1836 to 1842, partly by hand labour, and partly by machinery, by the Patent Arms' Company, established at Paterson, United States, where a capital of nearly £30,000 was expended without any beneficial result, except in gaining experience, both in the arms themselves and in the machinery required for their manufacture.

About the year 1837 the Florida war broke out, when the Seminole Indians, retreating into the 'ever-glades,' defied the power of the United States troops, and a comparative handful of savages resisted successfully, for a long time, all the forces sent against them. The Indians were as expert in the use of the rifle as their white invaders, who could make little, or no impression on them; in this strait the Government applied to the Author, who went to the seat of war with a supply of repeating arms, which even in their then comparatively rude state were found so effective, that more were ordered, and in the hands of the hardy-mounted Rangers, commanded by General Harney, who by their aid became the terror of the Red men, the war was soon brought to an end, for when the Indians saw their foes fire six times without lowering their weapons to load, they knew their former tactics were useless and they surrendered. This success, however, though very glorious for the Government, was exactly the reverse for the Author, for by exterminating the Indians and bringing the war rapidly to an end, the market for the arms was destroyed. They were, however, most successfully used by Commodore Moore, of the Texas Navy, as well as by Colonel Jack Hays and other distinguished Texan Rangers, during the wars with Mexico and the Indians from 1837 to 1848.

In consequence of the peace they were scarcely again employed, until the year 1847, when the Mexican campaign commenced, under the command of General Taylor, who having seen the utility of these weapons in Florida, where he was also in command, sent Captain Walker, of the Texan Rangers, to procure from the Author a supply of these arms; not one however could be procured, but by great exertion, commensurate with the exigencies of the period, a number were manufactured, and it has been stated that "those Texan Rangers, with Colt's repeaters, walked right into the towns and hamlets of the Mexicans and drove the population out against all resistance."

Colonel Charles A. May, the celebrated dragoon officer, in giving evidence respecting the arms said, "These arms were used with a great deal of effect, by General Harney, during the Seminole war;

since then I have had them almost constantly; and at the commencement of the Mexican war, was fortunate in procuring some of them; by General Taylor's order I armed one of my squadrons with them, and found them very useful. When I went last into New Mexico, I armed all my force with them. They were used with great effect. They possess very many advantages over the ordinary arms. They have great precision, and are shot with great facility, accuracy, and force. They are much more efficient than the ordinary arms. They can be used very readily while on horseback, while at full speed, with great accuracy. I have found no difficulty in shooting a ball through a buffalo. I do not know whether the Texan Rangers in the Mexican war were armed with these pistols by the Government, but almost every one had them. They were very much dreaded by the Mexicans. The Texans use them with great precision. I have no hesitation in saying, that I consider that ten men with Colt's pistols in their belts, and who understand their use, can go anywhere, and can keep off almost any force. I should not hesitate, with ten men, armed with these pistols, to go anywhere across the plains."

Such is the general history of the weapon, and in the manufacture, numerous improvements naturally suggested themselves, both in the arms and in the tools used in their production, until the former assumed their present shape, and the latter almost entirely superseded hand labour.

Figs. 12, 13, and 14, Plate 2, represent the arms as at present constructed, at the Author's manufactory, at Hartford, Connecticut, U. S. America. They differ from those formerly made, principally in the greater simplicity and the better proportions of the parts of the lock and the framework; important additions and improvements have been made in the loading lever, and rammer for forcing the balls firmly into the cylinder, (Fig. 12, Plate 2,) the employment of the helical, or spiral groove on the arbor, on which the cylinder turns, whose sharp edges are intended to prevent fouling, by scraping off any smoke, or dirt accumulating on the cylinder, from the lateral fire entering the centre opening; and the inclined plane leading to the recesses on the periphery of the cylinder, to direct the bolt below the opposite shoulder in the recesses; thus preventing the cylinder from being accidentally thrown too far, by the sudden action of cocking. The lock (as shown by Fig. 15, Plate 2, which is a skeleton arm, expressly arranged to exhibit the working parts,) is now composed of five working parts, instead of seventeen, as formerly, and it is obvious, that if the several parts of the machinery are made proportionally strong, for the work they have to do, so is

the arm rendered more efficient by the greater simplicity of the general construction.

In all arms having a moveable breech, it is desirable to bring the barrel and cylinder as nearly in contact as possible, in order to prevent the escape of lateral fire, and yet to leave freedom for motion, without friction; this is now effected by the base pin, on which the cylinder turns, entering a corresponding opening in the under part of the barrel, being there held in place by a key, passing through and bearing against the back end of the slot in the barrel, and the fore end of the slot in the base pin, which is thus drawn up to the bottom of the hole, and yet the barrel is prevented from being brought too close upon, or in absolute contact with, the cylinder, whilst its end is still held in its proper position with respect to the cylinder. In the event of any abrasion of the end of the cylinder, or of the barrel, by deepening the cavity, or filing the end of the base pin, the key can be driven further in, and the proper distance for the re-adjustment of those parts be maintained, whilst the essential rigidity of structure is secured.

In loading the present arm, it is necessary to draw back the hammer to the half notch, to allow the cylinder to be rotated freely by hand; a charge of powder is then placed in each chamber, and the balls, without wadding, or patch, are put one at a time upon the mouths of the chambers, turned under the rammer and forced down, by the lever, below the mouth of the chamber. This is repeated until all the chambers are loaded. Percussion caps are then placed on the nipples, when by drawing back the hammer to the full catch, the click, or lever is brought into contact with one of the ratchet teeth, on the base of the cylinder, bringing the nipple into the precise position to receive the blow of the hammer; the arm is then in a condition for being discharged by simply pulling the trigger; and a repetition of the same motion produces the like results, until all the chambers are discharged through the barrel.

Machinery is now employed by the Author, to the extent of about eight-tenths of the whole cost of construction of these fire-arms; he was induced gradually to use machinery to so great an extent, by finding that with hand labour it was not possible to obtain that amount of uniformity, or accuracy in the several parts, which is so desirable, and also because he could not otherwise get the number of arms made, at anything like the same cost, as by machinery. Thus he obtains uniformity as well as cheapness in the production of the various parts, and when a new piece is required, a duplicate can be supplied with greater accuracy and less expense, than could be done by the most skilful manual labour, or on active

service a number of complete arms may be readily made up from portions of broken ones, picked up after an action.

To minutely describe and illustrate the machinery would absorb too much time, and render this paper too voluminous, there being hundreds of distinct operations, involving a great variety of peculiar contrivances and mechanical motions; a general description of the mode in which the various parts of the arm are manufactured, will suffice to render the system clear to engineers, conversant with the effect of machines; and the specimens (placed on the table), which are entirely formed by machinery, will illustrate the description.

The manufacture of arms, both in Great Britain and on the Continent, is carried on almost entirely by manual labour, the various parts being forged, filed and ground into the requisite form, by workmen at their own houses, the barrels alone being forged, bored, and ground, in manufactories established for the purpose, and machinery being employed only for cutting out the stocks. At the Government small arms manufactory, at Enfield, under the intelligent direction of Mr. Lovell, steps onward have, however, been made, in the use of machinery for some portions of the work. Still no general uniformity among the parts can exist, and in America, where manual labour is both scarce and expensive, it was imperative to devise means for producing these arms with the greatest rapidity and economy, and at the same time with such uniform precision, as could only result from the use of self-acting tools.

The machinery requisite for constructing the repeating fire-arms, though at first view, like a cotton, or silk factory, apparently intricate, is in reality composed of the simplest elements, and consists in a repetition of known mechanical actions specially applied. It will suffice to describe the operations on a few parts, commencing with the lock frame, which is the basis of the whole, and to which all the other parts are adapted.

Like all the other parts, the lock frame is forged by swages, and its shape completed by one blow. The action of the machines commences by fixing the centre, and drilling and tapping the base for receiving the arbor, which having been previously prepared,—the helical groove cut on it, and the lower end screwed,—is firmly fixed into its position, furnishing a definite point from which all the operations are performed and to which all the parts bear relation. The facing and hollowing of the recoil shield and frame; the cutting and sinking the central recesses; the cutting out all the grooves and orifices, planing the several flat surfaces; and shaping the curved parts, prepare the frame for being introduced between

hard steel clamps, through which all the holes are drilled, bored and tapped, for the various screws ; so that after passing through twenty-two distinct operations, the lock frame is ready for finishing by hand, which consists in merely removing the rough edge, or burr, left by the machinery, and giving it the last polish and hardening.

The rotating chambered cylinder is forged from a solid piece of steel, turned, channelled, tapped, polished, and engraved, and then the chambers are bored out by a machine, which insures the most perfect precision of dimensions and uniformity of relative position.

In the same manner, the barrel, forged solidly from a bar of cast steel, is bored and completed to calibre and is then submitted to the various operations of planing, grooving the lower projection, beneath the barrel, with which the base pin is ultimately connected, tapped, and then rifled by a self-adjusting machine, which gives to the longitudinal grooves, the form of a contracting pitch spiral, commencing nearly straight at the lower end and terminating at the muzzle in a curve of much smaller radius.

All the various parts of the lock are made by machinery, each having its relative initial point to work from, and on the correctness of which the perfection depends.

So with the stock and the mountings, the ramrod lever, &c., all are formed and worked by different sets of machines.

In fact, all the separate parts travel independently through the manufactory, arriving at last, in an almost complete condition, in the hands of the finishing workmen, by whom they are assembled, from promiscuous heaps, and formed into fire-arms, requiring only the polishing and fitting demanded for ornament.

A large number of machines is necessarily required for these operations ; as it has been found advantageous to confine each one to its peculiar province, rather than to employ any more comprehensive machine, for several operations.

By this system the machines become almost automatons, performing certain labour under the guidance of women, or children, and thus the economy and precision of the manufacture are insured.

The improvements which time and experience have gradually introduced, have at length brought this fire-arm to its present state and have rendered it the reliable and efficient weapon for field service which it has proved to be, in the actions between the American and Mexican armies.

The official reports to Congress from the officers serving in that war, establish the reputation of the arm, and this is confirmed by Major-General Taylor, late President of the United States, who

whilst commanding the American Army in Mexico, wrote in these terms to the Author :

“ I have been much pleased with an examination which I have made of your new modelled repeating pistols and feel satisfied, that under all circumstances, they may be safely relied on;” and this opinion is universally concurred in by the officers of the United States’ Army and Navy, who have had ample opportunity of proving their efficiency in active service. Among others, Major Thornton, the Inspector of Fire-arms for the United States Army, stated, that “ After much firing and examination, the Board of Ordnance adopted Colonel Colt’s pistol for the service, as the best weapon presented for their consideration. Experiments showed, that six rounds of the pistol could be loaded and fired in a minute, with much greater accuracy and penetration than he had ever thought necessary for a pistol. A horseman could use it with one hand and have the other free to manage his horse. The dragoons and mounted riflemen should all be armed with these weapons, as in the hands of men accustomed to wield them, he considered them most efficient arms both for attack or defence.” *

* The “ New Quarterly Review ” for July 1852, contains the following apposite remarks:—“ We must now advert to the ‘ repeating principle,’ as applied to fire-arms in general, but more especially to pistols and carbines. It is to our transatlantic friends that we are indebted for the perfection of these weapons, for though, more than two centuries ago, various attempts were made to produce a series of successive discharges from one arm, without the necessity for re-loading, it is to Colonel Colt’s perseverance, energy, and mechanical skill, that the merit is due of having successfully vanquished all the difficulties that presented themselves in their construction.

“ Innumerable were the objections he had to contend with at the outset. Military men sneered at the idea as preposterous. ‘ They would always be liable to get out of order ’—‘ They would take too long to re-load ’—‘ They would besides always be missing fire,’ &c. &c. The Colonel did not, as many under the circumstances would have done, sit down and wage an idle paper war with his opponents. He did better—he set to work and demonstrated, that they none of them knew anything whatever of the subject on which they were all so confident. It was, however, natural that prejudice should be roused against an innovation of the kind—no invention of any value was ever yet otherwise received.

“ As regards the liability of the revolving pistol to get out of order, this was satisfactorily disproved, by a severe trial instituted by order of the Board of Ordnance of the United States, who directed a holster pistol to be discharged twelve hundred, and a belt pistol fifteen hundred times, cleaning them but once a day : after which ordeal neither of the pistols appeared to be in the slightest degree injured.

“ With respect to the cost of production, as almost every part is formed by machinery, hand-labour being only required in the finishing department,

Colonel Chalmers, R.A., has kindly furnished the diagrams of practice at Woolwich (Plate 3), made in the absence of the Author ;

Colonel Colt seems likely permanently to retain in his own hands the business which his ingenuity has created, for he will, of course, always be in a position to undersell any imitators that may appear. Greater security is also obtained from the same cause, for we find that, upon 'proof,' only one barrel and one cylinder burst out of 2,082 manufactured in the year 1850. The most perfect uniformity of detail is attained from the mechanism employed, for the several parts of each class of weapon are precisely similar, so that if any become damaged on service, a great number of available arms can be immediately compounded of those which have been partially injured.

"The ramrod attached to these pistols consists of a very clever but simple compound lever, which, forcing the ball effectually home, hermetically seals the chamber containing the powder, and by the application of a small quantity of wax to the nipple before capping, the pistol may be immersed for hours in water without the chance of a miss-fire.

"The movements of the revolving chamber and hammer are admirably provided for. The breech, containing six cylindrical cells for holding the powder and ball, moves one-sixth of a revolution at a time ; it can therefore only be fired when the chamber and the barrel are in a direct line. The base of the cylindrical breech being cut externally into a circular ratchet of six teeth (the lever which moves the ratchet being attached to the hammer), as the hammer is raised in the act of cocking, the cylinder is made to revolve, and to revolve in one direction only. While the hammer is falling, the chamber is firmly held in its position by a lever fitted for the purpose ; when the hammer is raised, the lever is removed and the chamber released.

"So long as the hammer remains at half-cock the chamber is free, and can be loaded at pleasure. The rapidity with which these arms can be loaded is one of their great recommendations, the powder being merely poured into each receptacle in succession, and the balls being then dropped in upon it, without any wadding and driven home by the ramrod, which of course is never required to enter the barrel.

"While carried in the pocket, or belt, there is no possibility of an accidental discharge of these pistols. Whenever it is required to clean the barrel and chamber, they can be taken to pieces in a moment, wiped out, oiled, and re-placed.

"The hammer at full cock forms the sight by which aim is taken. The pistol is readily cocked by the thumb of the right hand, a plan in every way far superior to the arrangement whereby the hammer is raised by a pull on the trigger ; this is in every respect most objectionable, the pull materially interfering with the correctness of aim, and the sear-spring having the duty of the main-spring to perform as well, is apt constantly to be getting out of order. Not so Colonel Colt's ; as regards the purposes for which they are intended they may be pronounced in every respect perfect.*

* Since this article was in type, we have been informed that Colonel Colt has just established here a manufactory for his revolvers. The building he has fitted up for the purpose is the one at Thames-Bank, near Vauxhall Bridge, lately in the occupation of the workmen engaged in making the mouldings, &c., for the New Palace at Westminster.

with pistols taken indiscriminately from the Great Exhibition. They extend from the 13th to the 21st of October 1851, and exhibit extraordinary force and precision of firing.

With a large revolving pistol, at a distance of 50 yards, out of sixty shots, five shots traversed the bull's-eye of 6 inches diameter, and thirty-nine shots hit within a square of 2 feet. Fig. 1.

In another case, at 50 yards, out of fifty-four shots, forty-six shots were placed within 2 feet square, of which six were in the bull's-eye. Fig. 2.

In the next case, at a distance of 100 yards, out of sixty-four shots, thirty-seven balls hit the target, of which two traversed the bull's-eye, twenty-seven missing the target; indicating that the sights were arranged for a shorter distance. Fig. 3.

With the small revolving belt pistol, out of forty-eight shots, at a distance of 50 yards, twenty-five shots hit within 1 foot square, of which thirteen were in the bull's-eye. Fig. 4.

"The gallant Colonel has applied the same principle to a carbine, which, from the facility it offers for loading, is admirably adapted for cavalry.

"Modern fire-arms," observes an able contemporary, 'as used for purposes of war, are just now in a transition state. Since the invention of the percussion lock, but little attention has been paid in this country to their improvement. The ill-concealed contempt with which purely scientific attempts are received, by those who make their only boast of being "practical men," is nowhere so prevalent as in England, and accordingly we find, that while we have remained stationary, the great continental military powers and the United States have not only availed themselves of each improvement as it appeared, but have stimulated invention by liberal patronage. The result of this obstinate adherence to an antiquated system has, fortunately, not yet been tested by an European war. Can we doubt what would be the result of an engagement between two bodies of troops, one armed with the English musket and the other with the needle-gun, which, taking the number of shots only into account, is $3\frac{1}{2}$ times as effective? Or, in the case of a frigate engagement, what would be the fate of any boarding party having to face a body of men armed with Colt's "six-shooters?" What an eager rush would there be to wipe off the burning disgrace! What sums would be squandered in trying to do that in a few months, which had occupied other nations years! The "practical men," no doubt, would attempt to console us, by calculating how many needle-guns and revolvers had got out of order during the campaign, and how bravely English soldiers stood up to be shot at by an almost invisible enemy.'

"As might be imagined, Colonel Colt's invention has called forth a host of imitations. We have examined and carefully tested these successively, and with the exception of two, or three, found them to be all decidedly inferior to the American original, which, of course, being protected by patent, cannot be copied in its main essentials. Consequently, none of the English revolvers have either the lever ramrod, or the separation between the nipples, which Colonel Colt regards as most essential."

[1851-52.]

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In another case out of eighteen shots, at a distance of 50 yards five traversed the bull's-eye, and all were lodged within 2 feet square. Fig. 5.

Further experiments will be made with these fire-arms, after being adapted to the standard percussion cap of the service, which the Author is preparing at the suggestion of the Board of Ordnance, as the present state of border warfare at the Cape, in India, and in other parts of the British Colonies, demands the adoption of repeating arms, and they must necessarily be adapted to the ordinary ammunition of the service.

The paper is illustrated by a series of diagrams from which Plates 2 and 3 are compiled.

DESCRIPTION OF PLATES 2 AND 3.

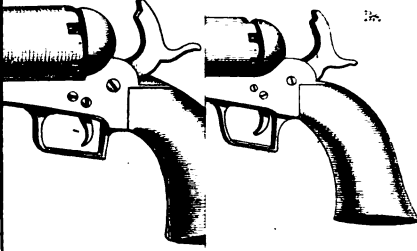
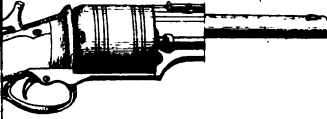
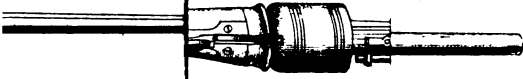
Plate 2.

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„ 2. Ditto, brought from India by Lord William Bentinck	<i>ib.</i>
„ 3. A Pyrites Wheel-lock Musketoon, in the Tower	33
„ 4. A Pistol of similar construction to Fig. 3; in the Rotunda at Woolwich	<i>ib.</i>
„ 5. An elaborately finished Spanish Gun of the 18th Century; in the Rotunda at Woolwich	34
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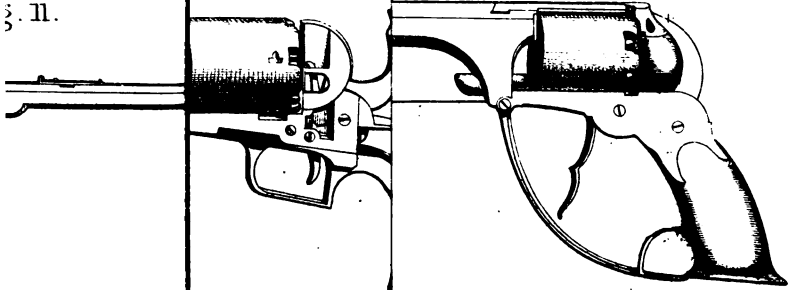
Plate 3.

Figs. 1 to 5. Diagrams of practice at Woolwich; with Pistols taken indiscriminately from the Great Exhibition in 1851

F.



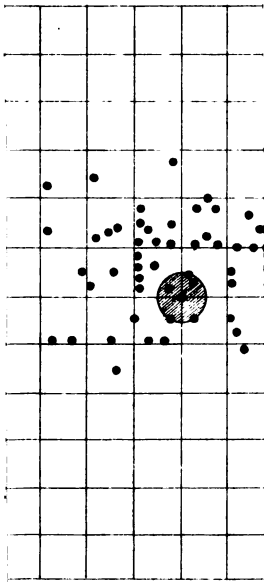
§. 11.



PRACTICE AT ROYAL

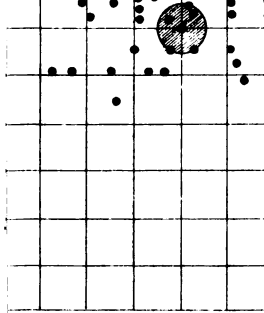
FIG. 2. — ARM. COLT'S LARGE REVOLVING PISTOL.

FIG. 2.



Range	50 Yards
Number of shots (from a Rest)	54
Hit	54
Miss	0
Above	41
Below	13
Right	23
Left	31

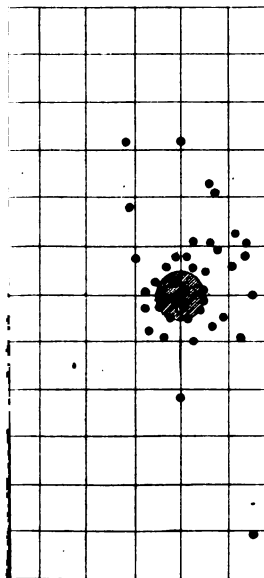
FIG. 3. — ARM. COLT'S LARGE REVOLVING PISTOL.



Range	100 Yards
Number of shots (from a Rest)	64
Hit	37
Miss	27
Above	15
Below	22
Right	18
Left	19

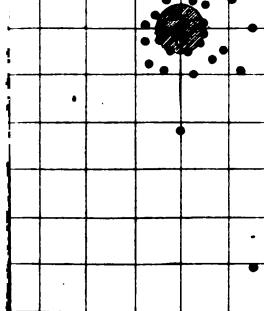
FIG. 4. — ARM. COLT'S SMALL REVOLVING PISTOL.

FIG. 4.



Range	50 Yards
Number of shots (from a Rest)	48
Hit	48
Miss	0
Above	25
Below	23
Right	33
Left	15

FIG. 5. — ARM. COLT'S SMALL REVOLVING PISTOL.



Range	50 Yards
Number of shots (from a Rest)	18
Hit	18
Miss	0
Above	10
Below	8
Right	13
Left	5



Colonel COLT, in answer to questions from the President, explained, that the course of this invention did not differ from that of almost every other innovation; it had to combat the prejudices of those using the old arms and the interested opposition of the manufacturers, and on that account he had been driven, not only to labour at attaining simplicity and efficiency in the arms themselves, but to contrive and adapt the tools and machinery for their production, with uniformity and rapidity and at the lowest cost. After he had undergone all the anxiety, labour and risk, attendant on bringing the arms to their present state, it was objected that the idea was not new, indeed that from an early period, repeating fire-arms with revolving chamber-breeches had been well known; he was now aware of this fact, but when he first commenced his experiments, he had not the most remote notion of anything of the kind having ever been previously attempted. At that time he was a very young man, and with only limited mechanical knowledge. His first invention was a fire-arm which would, in these days, be considered a very clumsy affair, although it was very similar to several of the weapons now being made in this country, and which were asserted to be superior to his pistols. It was necessary to explain, that the weapons first made were almost skeleton arms, but when he took out his patent and commenced their manufacture, the front end of the revolving-chamber was closed in, and the base end covered with a shield, to make the arm look well; the consequence was, that simultaneous explosion of several chambers frequently occurred, and this serious defect was only remedied by removing the plate, and the shield, and chamfering the orifices of the chambers. The first weapons also were made to be cocked and fired by the same action of pulling the trigger, but it was found impossible to take a certain aim with them, as it was necessary to exert as much force with the finger, as would overcome the resistance of the main spring in cocking, and the weapon deviated from the line of sight; besides which it could not be carried on half cock and was liable to explode the cap, if it received any accidental concussion.

Fig. 16, Plate 2, a combination of a bowie-knife and repeating pistol, made in 1836, would explain what he meant, and show how objectionable such an arrangement was in practice. Another modification consisted in having a ring trigger beneath the lock, on pulling which the hammer was raised and the chamber rotated, whilst the gun was fired by pulling an ordinary trigger. This construction required four, or five additional parts in the lock. At last, the present simple arrangement was arrived at, and he believed that it was almost impossible to have an accident, from the simul-

taneous explosion of several caps, or chambers, or to injure the weapons, without subjecting them to very rough usage, and the perfection of their fitting was so great, that they had been fired after immersion in water, or lying in the open air for a length of time.

The Honorable ABBOTT LAWRENCE, U.S. Minister, said, no words of his could so emphatically, or thoroughly express the general approval of these arms, as the Report to Congress of the Committee on Military Affairs, printed January 30, 1851, wherein it was stated, that experience had proved how difficult it was to contend successfully against savages with the usual arms of mounted men, the ordinary dragoon pistol and carbine ; whilst General Harney, an experienced officer, who had successfully used Colt's arms in Florida stated, that they were the only weapons with which the United States' troops could ever hope to subdue the wild and daring tribes, against whom they were called to act ; but that with them, a few bold men, well skilled in the use of these weapons, could encounter and scatter almost any number of savages.

Being a civilian, Mr. Lawrence only knew the merits of these weapons from general reputation, and from their having been adopted by the United States' Government, after long trials and considerable experience in their use. In the army generally, they were considered the most efficient weapons ever introduced, particularly for border warfare, against savage tribes, whose cunning, hardihood, courage and skill, rendered them very formidable enemies. It was his opinion, that the British troops would never successfully oppose the Kaffirs, until they were supplied with these repeating fire-arms, and he was much gratified, that one of his countrymen should have produced a weapon, which was admitted, as far as it was yet known in Europe, to be superior to any other arm of the kind, and he was assured, this gratification would be participated in by all around him, as they must remember, that the British and the Americans were brethren, sprung from the same Anglo-Saxon stock, speaking the same language, and inheriting the same feelings which animated the subjects of these realms. He felt convinced, that the arm would have a fair trial in England, that no undue prejudice would be permitted to prevail, and that the invention would be examined and tested as if it had been brought forward by a British subject. There was room enough for inventions of all countries, and all that could be desired was, that in a fair and proper spirit of rivalry, this invention should be considered and examined with that good feeling and kindness which should animate all men, in the great cause of promoting the arts and sciences, and the application of science to art.

When he came to the meeting he had not any idea of being called on to express an opinion, but having risen, he must thank the members for the manner in which they had received his countryman's paper, and he trusted, that though apparently a warlike subject, its discussion would be as productive of harmony in the Institution, as the general use of the weapons in warfare would certainly be productive of peace, for the most effective weapons were the most efficient peace-makers, and though he was himself a peaceable man, in every sense of the word, he was convinced that to maintain peace it was necessary always to be prepared for war; every improvement in fire-arms, therefore, reduced the cruelty of war, and tended to the perpetuation of peace, and hence he should be an advocate for any improvement, which would tend to diminish the ravages of war, whether between civilized nations, or against savage tribes, in the now inevitable spread of the white man, in his course of emigration.

Commodore Sir THOMAS HASTINGS, R.N. regretted, that he could add but little interest to the discussion, as the paper had fully described the weapon and its merits; he must however state, that Colonel Colt had afforded the officers of the Ordnance every facility, for attaining a complete knowledge of its merits, or defects, and he believed the general impression was, that no fire-arm of that size ever possessed so much power. It must be acknowledged, that war was a great evil, particularly between civilized nations, but it was equally true, that giving the utmost perfection to the weapons used, was the surest manner of annihilating modern warfare. It was well known, that in some of the great battles of the ancients, more combatants fell, than during a whole campaign of modern armies, and in the battle of Lepanto, the last great hand-to-hand fight, fifty thousand combatants fell, which exceeded the numbers killed in all the naval engagements of the last and present centuries. Every step towards perfection, in weapons of war, was a humane improvement, and on that ground, independently of the necessity of arming the troops in the most efficient manner, the attention of the Ordnance had been carefully directed towards these and other improved arms, and the result of the trials had been to convince him and other officers, that they had rarely seen better practice, than with Colt's pistols. The ordinary infantry musket was considered a useful weapon at one hundred yards, but beyond that distance, it was mere random firing; now Colt's large pistol was equal in effect to the musket, at that range, and for use against savage tribes it must be a most effective weapon. The tactics of the Kaffirs were to tease an out-post sentry, at a distance, until they had drawn his fire, and then to spring on him before he had time to reload; and in attacking a

convoy, which was generally done in a defile, a rush was made, which induced the fire of the whole guard and the men were left defenceless, except by the bayonet, which was not effective against long lances, or assagais. Now nothing could be more perfectly adapted to meet these tactics, than the revolvers, because after the savages had received the musket shots, they would rush up in a body to close quarters and thus render the effect of the pistols more certain. After a few experiments of this kind, the savages would have become acquainted with the nature of the weapon and the convoys might almost be sent without escort. He was of opinion, that these arms would be found extremely useful for troops on special duty and eventually it might be advantageous to introduce them generally into both services.

Captain Sir E. BELCHER, R.N. said, that some time ago he was in Texas, among the American troops, and there saw Colt's revolvers used with great effect and precision, and had never heard of an accident occurring from simultaneous explosion of the chambers. They were generally used by the mounted Rangers, who appeared to rely on them, for their effective attacks on the enemy.

He would suggest to Colonel Colt, whether it might not be advantageous so to modify the form, as to make the breech end of the barrel conical, and to introduce it into the mouth of the rotating chamber, in order to prevent the loss of power arising from the present escape of lateral fire, between the chamber and the barrel, and to throw the fire obliquely forward. In the old Chinese jinghals this arrangement was made, evidently from experience of its utility.

Colonel COLT explained, that such an arrangement, as had been suggested by Sir E. Belcher, had been tried, and was in fact now used, in some of the imitations of his revolvers, but it added to the complexity of the weapon, which he had desired to reduce to the utmost simplicity, and it was not found, in practice, that any serious loss of power resulted from the small escape of the lateral fire, that actually took place in his revolvers, as from the accurate fitting of the several parts, the mouth of the chamber was brought into very close proximity with the base of the barrel, and yet permitted the free rotation of the chamber.

Sir THOMAS HASTINGS agreed with Colonel Colt, that there was not any necessity for the arrangement suggested by Sir E. Belcher; since everything which detracted from the simplicity of construction of the weapon, must be prejudicial to it, and the essential difference between the Chinese jinghal and Colt's revolver was, that the former was a cumbrous, unwieldy instrument, whereas in the latter there

was, in the least possible compass, a weapon which, in the hands of men conversant with its use, would do as good service as the ordinary musket and could throw five, or six balls without stopping to reload. The reports of trials made under the superintendence of the Officers of the Board of Ordnance, clearly pointed out these advantages, and those gentlemen acted so conscientiously and made their reports with such fidelity, that perfect reliance could be placed in all their statements. He made these observations, because he saw on the walls some diagrams of the firing at targets, at Woolwich, which corroborated his opinion of the utility of these arms; and it was only justice to Colonel Colt to do so, as since his arrival in England, that gentleman had afforded every facility for the perfect understanding of the arm of which he was the inventor.

Sir T. Hastings entirely participated in the feelings so ably expressed by the Hon. Mr. Lawrence, and trusted that the relations with our Transatlantic brethren, and indeed with all the civilized world, would long remain on a footing of the strictest amity.

Captain RIDDELL, R.A., said, that such ample opportunities for proving the utility of the revolvers had been afforded, and such a clear account of the invention had been given in this paper, that it was incumbent on him, as a British officer, to add his thanks to Colonel Colt, for the efficient arm he had introduced to the notice of the Government and which, he did not doubt, would soon be employed for those branches of the service in which it was so well calculated to be useful.

Mr. A. B. RICHARDS said, that through the courtesy of Colonel Colt, with whom he had no previous acquaintance, he had ample opportunity of trying the revolvers, and having some considerable experience in the use of fire-arms, he ventured to state, that he never had met with any pistol which carried with greater precision. Out of six shots from one cylinder, five of the balls touched each other in the target, at a distance of fifteen paces, in a shooting gallery. He did not think that greater accuracy could be required, nor could it generally be attained without hair-triggers. For active service, particularly against the Kaffirs, this weapon would evidently be invaluable, and he felt convinced that the authorities would soon see the propriety of adopting it.

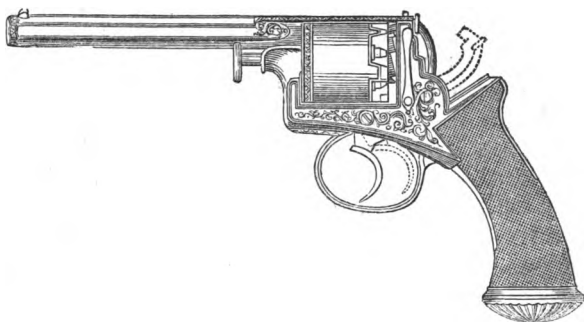
Major-General Sir C. PASLEY, R.E., had not officially any experience of the weapons under discussion, but he had examined them attentively and knowing the care with which the trials for the Board of Ordnance were conducted, and seeing the results, he formed a high opinion of their merits, particularly as subsidiary arms for troops engaged in warfare against savage tribes, or on special and

detached service, and he felt assured these capabilities would be fully appreciated by the proper authorities.

Mr. J. FREEMAN said, that during the course of the Great Exhibition, he had been attracted, in the American department, to Colonel Colt's revolvers, and perceived their merits; he begged however to direct attention to a pistol on a somewhat similar principle, made by Messrs. Deane, Adams, and Deane, and would ask one of those gentlemen to explain wherein its merits consisted.

Mr. ADAMS, exhibited and described a revolver of his invention.

Fig. 2.



The barrel, the lock-frame and top-bar were all forged out of one piece of iron; the chamber to contain five charges, revolved on a centre pin, which could be either drawn entirely, or partially out, as was required and was held in its position by a side spring; the toothed ratchet was secured to the base of the chamber by two screws, so as to admit of its being renewed, when it was abraded by use, and motion was given to it by a ratchet pall, connected with the hammer, which was lifted by pulling the trigger. The hammer moved on a transverse pin, and was pressed down on the nipple, by a back spring in the stock, being connected with it by a swivel link; the trigger was kept in position by a horizontal bent spring, and had attached to it the hammer-lifter and the ratchet pall; the point of the former fell into a notch in the base of the hammer, so that as the trigger was pulled, the hammer was raised, until the rounded portion of the base, acting as a cam, forced the lifter out of the notch, and allowed the hammer to descend on the nipple and to explode the percussion-cap. On withdrawing the finger from the trigger, the lifter and ratchet pall descended and again slipped into the notches of the hammer and the chamber, in readiness for repeating the operation of firing. The lifter was retained in contact with the hammer, by a small flat spring, the upper end of which was

attached to the pall, while the lower end acted upon the lifter, which, in turning on its centre, brought the lower prolongation against the spring, below the centre, so as to press the upper end in the proper direction, in order that its action might be certain.

The rotation of the chambers was obtained by a ratchet pall, acting on a tooth each time the trigger was pulled, thus causing the chambers to revolve, so far as to bring a nipple into the proper position for receiving the blow of the hammer, and in that situation it was held by a projecting stop on the back of the trigger.

In order to load the chambers, it was necessary that they should revolve free of the stop; this was effected by pressing inwards another stop, attached to a spring on the side of the lock, which engaged the point of the hammer and prevented it from descending on the nipple, until the chambers were loaded, when on the trigger being pulled, the side spring stop was released and resumed its original position, leaving the weapon ready for action.

The bullets were cast with a small 'tang' on them, which served to fix a wad on each, thus no ramrod was required in loading, the bullets being merely pressed in with the finger. The aperture of the barrel was slightly expanded at the lower end, to admit of the bullets entering more readily in firing. The rifling of the barrel was the reverse of the ordinary system, as it consisted of three projecting 'feathers,' or ridges, extending the length of the tube, leaving very wide grooves between them.

It would be observed, that the cocking and firing were performed by the same action of the trigger; therefore the rapidity of firing was proportionally great; the arm was very light, its construction simple, and its action certain.

With respect to the mode of manufacture, every portion to which self-acting tools had been found applicable, was planed, bored, turned, slotted and rifled by machinery.

Mr. A. B. RICHARDS inquired, whether the principle of the weapon just described by Mr. Adams, was not identical with that brought before the public many years ago, in connexion with a pistol with five, or six revolving barrels, which he believed had been laid aside, because it was found, that after being used for a short time, the spring did not retain sufficient power to bring down the hammer with force enough to explode the cap, and if the spring was made stronger, it required the exertion of so much strength, that the weapon was depressed in firing, and taking a correct aim was nearly impossible. There did not appear to be any advantage in the power of firing so rapidly, as on service it was certainly not necessary to put five, or six bullets into the same adversary, and whilst directing

Colt's revolvers from one point to another, there was no difficulty in cocking the pistol with the thumb, using only one hand.

He begged also to ask, whether a paper, headed "Experiments with Fire-arms," dated "Woolwich, 10th September 1851," purporting to be a report of some trials of Colonel Colt's and Mr. Adams' revolvers, was issued officially, as the results were very different from those which were generally understood to have been attained; and as the paper appeared to have been extensively circulated, it was well to arrive at a true understanding of its value.

Sir T. HASTINGS stated, that so far as he was cognizant of the matter, no report of the comparative merits of Colonel Colt's and Mr. Adams' revolvers had been officially published by the Board of Ordnance.

Captain RIDDELL corroborated the statement of Sir T. Hastings.

The SECRETARY, at the request of the President, read two communications from Colonel Chalmers, R.A., relative to the diagrams of practice with Colonel Colt's arms,* permitted by him to be transmitted to the Institution, in which he stated "I have seen the printed document entitled 'Experiments with Fire-arms,' as published by Mr. Adams; it is not official."—"I have for some time had two of Colonel Colt's revolvers under severe trial, and with good caps they never miss fire."

Mr. PLINY MILES said, the principle of construction of Mr. Adams' revolver had been tried in America long ago, and had been abandoned. Colonel Colt had at one time fallen into the error of using it, as was evident from the bowie-knife pistol exhibited. Mr. Miles carried a weapon like that described by Mr. Adams, for nearly two years, in the Western States and the valley of the Mississippi, but he never could make it a serviceable arm, as it required the exertion of so much strength in the finger, to revolve the cylinder, and lift the hammer by the same pull on the trigger, as fired the charge, that the muzzle was almost invariably depressed, or turned out of range, and he never could be certain of hitting a mark: he therefore got rid of it, and purchased one of Colt's revolvers, which he found just as effective, as the other was inefficient. He now rarely missed a shot, even at birds, and the revolving of the cylinder, being performed by the operation of cocking, the firing could be rendered almost as delicate as by a hair-trigger, so that the most accurate aim could be taken.

Mr. C. MAY, as the only member of the Society of Friends present, rose to order: he thought the meeting had erred, in quitting the

* Vide ante p. 48, and Plate 3.

question of the mode of manufacture of these weapons, for a discussion upon their relative merits, or their destructive qualities, which he submitted, were not proper topics for the Institution of Civil Engineers; he thought all weapons might be dispensed with, except for protection against wild beasts.

From an examination of the specimens before the meeting, he was of opinion, that the machinery used in the manufacture was not of the accurate description generally employed in this country, the tool marks were more evident, than in the machine-made work produced at Manchester, and no information had yet been given as to the price of production. He begged Colonel Colt to give such information on these points as he considered could with propriety be imparted to the meeting.

Mr. RENDEL, *V.P.*, agreed with Mr. May, that the efficiency of the arms was a question which would be more properly considered by the authorities at Woolwich; it would be more interesting to the meeting to know what kind of machinery was used in the manufacture of the arms, and to be informed what process each piece went through, in arriving at the state to form component parts of so apparently well-constructed a weapon, as that now submitted by Colonel Colt, who he would beg to enter into such details as he judged fit, relative to the manufacture.

Colonel COLT said, he thought the process of manufacturing had been as fully described in the paper, as could be done without prolixity; he would however revert to whatever had been omitted in the paper, or in the previous part of the discussion; but it was scarcely practicable to give a clear idea of the process of manufacture, without diagrams of the machines employed, and even they would hardly convey a correct impression of the action of such tools.

Each separate piece of the arm, was forged hot, under swages, and then underwent a series of operations in machines, each adapted especially for one peculiar service. This had been found more economical than using comprehensive tools, and a greater degree of uniformity of structure was obtained. The mode of proceeding with one part would give an idea of that for all the rest. Taking, for instance, the lock frame; the swaged block of metal was held in clamps, and the centre hole drilled and tapped for the base pin, which was then inserted, in order that each subsequent operation should have relation to, and accord with the position of that part of the arm, which served as a common centre. The lower inside curve was then cut, the various slots, grooves, spring bearings, &c., were cut through clamps, by which the piece was presented to the various

automaton machines, and last of all, the operations of centring, drilling and tapping all the holes were performed, also under the guidance of clamps. That piece passed through twenty-two distinct operations, and after leaving the last machine, it was only requisite to remove by hand the rough edges left by the tools; thus a clear idea could be formed of the amount of manual labour employed.

In making the cylinder, or chamber, which was also forged from a block of steel, annealed, the centre hole was first drilled, then the exterior was turned and engraved (also by a machine), then the ratchet teeth were cut out of the solid metal, because it had been found, that the ratchets, which were attached by screws, were apt to get loosened by service and the arms were rendered inefficient and dangerous; the holes for the nipples, and the charge chambers were then bored on a kind of universal chuck, the muzzles were chamfered, the stop grooves cut and the cylinder was completed fit for use.

The barrel forged solid, by swages, from a bar of steel, was first bored, and then rifled by a very simple machine, in such a manner as that the groove, at the breech end, was almost straight, and gradually contracted the pitch to a sharp curve at the muzzle, to give to the bullet the proper rotation in delivery; the exterior of the barrel was then finished in the various machines and the lever ramrod was attached.

It was unnecessary to extend this kind of description of processes, which would be readily understood by all engineers, and it must be evident, that a degree of uniformity and precision was arrived at, which could not be attained by any other means. Nor could the quantity required be produced by manual labour; in his factory at Hartford, there were now thirty thousand weapons in various stages of progress, and the demand was so great, that he contemplated increasing the number to fifty-five thousand, to meet the requirement of the market; three hundred persons were employed, and about one hundred arms were finished per diem.* This must be evident proof of the paramount necessity for machinery, wherever combination might interfere with the work being done, and more especially in a country like the United States, where manual labour really could not have been procured, to produce such a quantity, independently of the great merit of the positive uniformity of the

* It has since been stated, that by further subdivision of the operations, and by additional machinery, two hundred and fifty pistols have been finished per diem, or fifteen hundred arms per week have been completed at the Hartford factory, by less than five hundred workpeople.—*Sec. Inst. C. E.*

arms, which had been proved, by picking up the disabled arms after an action, when seventy-five per cent. of perfect weapons were readily made up fit for use.

In round numbers it might be stated, that supposing the cost of an arm to be 100, of this the wages of those who attended to, and passed the pieces through the machines was 10 per cent., and those of the best class of workmen engaged in putting together, finishing and ornamenting the weapons, was also 10 per cent. ; thus leaving 80 per cent. for the duty done by the machinery.

The weights of the several weapons were—

		lbs.	oz.
The Army, or Hostler Pistol		4	4
The Navy, or Belt Pistol		2	6
The Pocket Pistol, 6-inch Barrel		1	12
Ditto 5-inch Barrel		1	10
Ditto 4-inch Barrel		1	8
Ditto 3-inch Barrel		1	6

Mr. HODGE was happy to have an opportunity of adding his testimony to the merits of Colonel Colt's weapons, and to the simplicity and effectiveness of the machinery employed in their manufacture. The skill displayed in the design of the various machines, was very remarkable, but it was evidently the result of necessity, arising from the difficulty and expense of obtaining skilled labour in the United States ; this had stimulated the inventive faculties of all engaged in mechanical pursuits and as a general rule, nothing was made by hand that could be executed by machinery. Perhaps one of the most striking evidences of practical skill was the variety of crooked cutters used for shaping, not only in Colonel Colt's armoury, but in all the machinery factories in America, and it would answer the purpose of English manufacturers, to send an intelligent foreman over to the States, to examine what was now being done there. The gun-makers at Birmingham might certainly learn much from studying Colonel Colt's system of manufacturing, and their work would be produced at infinitely less cost, if they abandoned the system of employing a number of men, each working independently in his own ill-lighted, badly ventilated, and inconvenient workshop, forming and filing up, without any uniformity, parts of arms, which would be produced in much larger quantities, in less time and with perfect identity of form, by the simple machines used by the Americans.

He thought much was due to the greater amount of intelligence to be found among the working classes in the States, than among the corresponding class in England. Most of the American mechanics were not only good handy-craftsmen, but from their habits of thought and determination to 'go a-head,' were continually devising means of

executing their work with rapidity ; thus new machines were constantly invented, and the education and intelligence of the working classes increased daily, because there was stimulus for thought and a consciousness in the mind of every man, that there was an ample field before him, in which he must prosper, if he used any exertion. It was ardently to be hoped, that by the extension of education among the working mechanics in England, the intelligence and inventive genius, which at present appeared confined in a great measure to a certain class, would extend to the working mechanics, whose manual skill was beyond all praise.

Colonel COLT, in answer to questions by Professor Cowper, explained, that the majority of the tools used were revolving cutters, at a slow speed for heavy coarse work, and with great velocity for fine finishing, or light operations ; in slotting, shaping, and drilling, the tools were guided by steel clamps, which insured that uniformity in the several parts, which was one of the distinguishing features of his manufacture. Special machines were used, for all special operations, as general planing machines had not been found advantageous.

Mr. HODGE said, that although revolving cutters were certainly used in machine shops in England, they were not employed to the extent they might be ; it was, however, the use of the shaping cutter that should be more extensively introduced ; he had never seen such good work in any factory as in Colonel Colt's, and it must be entirely attributed to the judicious use of the tools he had mentioned.

The machine for rifling two barrels at the same time, by means of an excentric wheel, was very beautiful, and he must repeat his regret, that machines were not more used in the manufacture of arms in this country.

Mr. EVANS stated, that in the year 1822, he manufactured a number of flint lock revolving chambered-breech fire-arms, for Mr. E. H. Collier, whose patent, with that of Mr. Coolidge, had been mentioned in the paper.* Those arms were chiefly made by machinery which was still in his possession.

Mr. Evans had also made machinery for the Government establishment at Enfield, by order of Mr. Lovell, Inspector General of Small Arms, and the arms made there were, to a considerable extent, produced by those machines.† The rifling especially was so executed, and the machine permitted the pitch of the groove to be varied, according to the will of the operator.

Mr. HODGE expressed his gratification at hearing from Mr. Evans,

* Vide ante page 36.

† Vide ante page 45.

that machinery had been introduced into the Government Small Arms Manufactory, as Mr. Hodge had suggested it to Mr. Evans six years ago and had for some time pressed it unavailingly on his notice.

Mr. C. MAY begged to inquire of those who were well acquainted with the working classes in both countries, whether it was their deliberate opinion, that the American mechanics were better educated than their brethren in England. He had not been in the States, but from all he could collect he had arrived at the conviction, that the best English mechanics were better than the Americans; and he must say, that no work he had ever seen from America was equal to that produced in the machine shops of Manchester, Leeds, and other places, enjoying a reputation for good work.

Mr. GLYNN was much inclined to agree with Mr. May, and the eminence so frequently, and at times so rapidly, attained by English mechanics, would seem to corroborate those views: indeed there was scarcely any field in which more men had risen to distinction, by the exercise of skill and talent, than in civil and mechanical engineering. This could not be the case, if they had not education as well as innate talent.

Mr. HAWKSHAW was of opinion, that if the term 'education,' meant 'book-learning,' the working classes in America, particularly in the cotton factories, possessed a greater amount of education, than the corresponding class in England; but if 'education' meant the special instruction, which enabled a working mechanic to perform his daily labour, with credit to himself and with profit to his employer, the English mechanics were the better educated class. He however thought, that as far as general education was concerned, the American workmen might be considered as more advanced.

Mr. J. SCOTT RUSSELL apprehended, that the comparison must be drawn between the better men of the working classes and not between the mere handicraftsmen, who he believed to be nearly identical in attainments in both countries. He thought, that Mr. May must have formed his opinion, from observations made at that paradise for the workmen, the works of Messrs. Ransomes and May, at Ipswich, where they were generally better educated, better conducted and better cared for, by their employers, than in almost any other establishment he had ever visited. Now Mr. Russell did entertain some alarm as to the ultimate position of English mechanics, with respect to that of the workmen in Prussia and in other parts of the continent. For the last fifteen years, the artisans of Germany had been receiving an amount of education, which could not fail, eventually, to render them formidable competitors,

unless the English workman added education to his present almost matchless manipulative skill. He was glad, that the subject of the education of the working classes had been mentioned at the Institution, because he felt assured, it was from thence, that the first movement should emanate, for the introduction of a comprehensive scheme of education for that valuable class of men, the English mechanics.

Mr. W. B. ADAMS said the men worked harder in the United States, under the influence of better wages, but he did not think the produce was generally so well finished as in England. There was certainly room for a greater extent of education among the working mechanics here, and more especially for instruction in the mechanical principles of the tools and machines, the application of which was their daily occupation. The employers would find great benefit result, from encouraging and even enforcing education among the working classes.

Mr. HEPPEL said, he had for some time a considerable number of Prussian workmen in his employment, manufacturing engines and general machinery; they were better informed on general topics, but the English mechanics made themselves more really valuable, by their more positive knowledge of their duties, their greater appreciation of the necessity of precision and of accurate adjustment, and their greater readiness in emergencies.

The Hon. ROBERT JAMES WALKER (late Secretary U. S. Treasury) said he rose with diffidence to speak of civil engineering, in an assembly where the best authorities were continually heard on that important subject; his attention had been chiefly directed to finance, political economy, and jurisprudence, but he was fully alive to the advantages of cultivating a science which conferred such inestimable benefits on mankind generally. He felt but little qualified to enlarge on the character and use of the celebrated revolver, of his friend and countryman Colonel Colt, as the principal object of his social and political course had been, to encourage free commerce and intercourse between all countries and thus to render gunpowder and fire-arms unknown quantities in the future career of England and America.

It must be evident to all thinking men, that civil engineering was one of the most important professions connected with the advance and progress of the human race. To that profession was due the praise of having constructed railroads, bridges, and canals—improving rivers and harbours—building steam engines, for locomotion upon land and water—and substituting machinery for manual labour, (greatly for its benefit) in nearly all industrial pursuits.

To the engineers must be attributed the construction, in the

United States, of nearly 4,000 miles of canals, and upwards of 10,000 miles of railroads; and by their aid, at least one great railroad would be constructed across the American continent, from the Atlantic to the Pacific.

By the aid of the same great profession, a ship canal would no doubt, eventually, be cut through the American isthmus. This would be, in its consequences, the greatest work of civil engineering yet undertaken by man; and the American pioneers, now engaged in the preliminary railroad, would be greatly pleased, to obtain the aid of the Institution of Civil Engineers, and of its distinguished members, in connection with their own eminent engineers, in promoting the speedy construction of that great work, not only for the benefit of England and America, but of the world at large.

Civil engineering was the application of mind to matter, and was perhaps more important in its general effects, in America, than in Europe, inasmuch as labour being much dearer in America than in England, it became necessary, in order to enter into successful competition, to substitute more machinery for manual labour, in all manufacturing operations, and thus the inventive faculties were roused, and innumerable machines were introduced which, but for necessity, would never have been thought of. And here he might be permitted to remark, that, whilst it would not perhaps be possible at present to assemble in America so large a number of distinguished and scientific engineers, as were found in this Institution, yet he thought, that, education was more widely diffused among the industrial classes in the United States; that among the operatives, there were more educated heads at work than in England; and that must in a great degree be received as one of the chief causes of the progress and success of America. The educated industrial classes applied their intellect, from day to day, to improvements in the operations in which they are concerned, and hence it was, that many of the most useful inventions and discoveries had originated with the working mechanic handicraftsman.

With respect to the repeating fire-arms, the account of which had been read to the meeting, he was bound to state, that, during the last war with Mexico, the use of those weapons became a subject of careful discussion in the American Cabinet, of which he was then a member. From the evidence laid before the members, the decision was unanimously in favour of the employment of Colonel Colt's revolvers, in conformity with the recommendations of the distinguished officers who had used them. The results were most brilliant and successful in those campaigns, more especially in guerilla warfare; and he believed, that the sentiment of the army, the navy, and

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those who were from necessity obliged to be prepared for offensive, or defensive warfare, was clearly and decidedly in favour of the general use of Colt's repeating fire-arms.

General MACNEILL hoped he might be permitted to revert very briefly to the merits of the repeating arms invented by his friend and countryman Colonel Sam Colt; he used the term 'invented' advisedly, because he was aware of the progressive steps, by which the present efficient form of the weapon had been arrived at; he knew also, that Colonel Colt was not cognizant of any previous attempts to produce such weapons, until he visited Europe to secure his first patents, and he had watched, with more than ordinary interest, the gradual application of the ingenious self-acting tools employed in the manufacture of those arms.

As an old military man he had the means of obtaining the private opinions of most of the distinguished officers of all grades, whose public testimony of the merits of the arms in actual warfare, was embodied in the "Report of the Committee on Military Affairs" addressed to the Senate of the United States, January 30th, 1851 (31st Congress, 2nd Session) and without trespassing on the time of the meeting by entering into particulars, which had been so extensively circulated in that report, he might state, that all military men coincided in the opinion, that for detached service, reconnoitring parties, convoys, out-post sentries, and generally for service against savage tribes, or border warfare, Colt's repeating arms were most efficient and it was an acknowledged fact, that without their use, the late campaigns of the United States armies could not have been so speedily, or so satisfactorily terminated. It was proverbially difficult to induce old soldiers to try new weapons, and there had been the usual amount of reluctance to try, and then to recommend the adoption of the repeating arms, but there was no resisting the evidence of actual practice, and the demand for them in the frontier corps, soon became as urgent, as it was among the borderers, who were not so slow to appreciate the advantages of such weapons.

The machinery used in the manufacture of these arms was equally remarkable for its simplicity, the ingenuity displayed in the adaptation of the tools, and the satisfactory manner in which all the various processes were conducted, so as to produce weapons, that were not only trustworthy and efficient, but so perfectly identical in all their parts, that in assembling a pistol, the several pieces were taken promiscuously from a heap, and the arm was finished almost without manual labour. It must be evident, that this was a great advantage, in a country where labour was so costly and where the borderers, the

isolated pioneers of civilization, who most required these weapons, must repair them, as well as use them.

As however it had been General MacNeill's lot, for many years past, to devote his energies to the peaceful occupations of Civil Engineering, he would prefer reverting to the subjects so well alluded to by the Hon. Mr. Walker, and he trusted, that in future the only contest between England and America, would be for priority in undertaking, and rapidity in executing, great engineering works for the benefit of the human race. In no way could this desirable end be so well attained, as by combining the energy and comprehensive enterprise of American engineers, with the proverbial science, skill, intelligence and good faith of the English engineers, who would find in the United States a hearty welcome, and a fine field for the exercise of their professional talents.

It had been his good fortune, whilst actively engaged in the execution of extensive engineering works, to have under him many young men, Scotch, Irish, and English who all arrived with the same simple story, "they wanted work;" and though he could not give them such employment as their talents and acquirements warranted, he afforded them such occupation as he could command, and in a short time, though they might have commenced as mere chain draggers, or assistant surveyors, at the rate of a dollar per diem, they soon progressed, and in a few years some of them were realising large incomes. He did not claim any merit for thus advancing the career of these young men; they had served him well and obtained the just reward of their talents and integrity, but in all cases he felt that he was only returning, in a slight degree, the hospitality and kindness he had experienced, at the hands of Telford, George Stephenson, Walker, and other eminent engineers, when he visited England many years ago, as a young Captain of Engineers, with his brother officers Whistler and Knight, with whom he was associated, in a journey undertaken by order of the United States Government, for the inspection of the great works of art in Great Britain. On that occasion, it was his good fortune to be brought into contact with Mr. Robert Stephenson and Mr. Locke, at that time commencing the works which would hand down their names to posterity, as the worthy successors of the eminent men he had previously mentioned. He was proud to have known those two engineers, and to acknowledge, that whatever useful work he had undertaken, and whatever success he might have obtained in his own country, had been materially aided by the intercourse he had been permitted to have with those gentlemen at an early period of their professional career.

Since the period to which he alluded, a great change had taken place, in the means of acquiring engineering knowledge ; at that time he was told, that "engineers, whose opinions were worth having, were too busy to write books ;" but now at the meetings of the Institution, not only were papers brought forward and publicly discussed, but the most eminent authorities of all professions entered with interest into the debate, and the results were freely published to the world. Although perhaps there might not be the same class of works executed in the States, as in Great Britain, yet there was much originality in many of the works of American engineers, and it should be his study to induce a liberal interchange of scientific and professional communications, between the American societies and the Institution of Civil Engineers, and he was sure, that the Hon. Mr. Walker would induce the Government to transmit all the scientific documents published by its orders.

Science knew no distinction of country ; the whole world was an open field for the exercise of engineering skill, and in that field, professional brethren of all nations should strive in the contest for the noble end of doing the greatest amount of good to the greatest number of the human race.

December 2, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

The following candidates were balloted for and duly elected :— John Joseph Bagnell, William Main Crosland, John Brough Palmer, Charles Sells, John Pigott Smith, John Hooke Taunton, and John Wilkinson, as Associates.

The discussion upon the Paper No. 862, "On the application of Machinery to the Manufacture of Rotating Chambered-breech Fire-arms," by Colonel S. Colt, being renewed, was extended to such a length as to preclude the reading of any communication.*

The President announced to the Meeting, that a Telford Medal had been awarded to Mr. G. B. Bruce, M. Inst. C.E., for his Paper "On the Border Bridge," and that, in consequence of his immediate departure for India, the Council proposed to present the Medal at this Meeting, if such a proceeding met with the approbation of the Members. The proposition being favourably received, the President announced to Mr. Bruce that the Medal would be immediately transmitted to him by the Secretary.

* Vide ante page 30.

December 9, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

NO. 855. "An Account of the Works on the Birmingham Extension, of the Birmingham and Oxford Junction Railway." By CHRISTOPHER BAGOT LANE, Assoc. Inst. C.E.

It is proposed to lay before the Institution, a short sketch of the Birmingham Extension, of the Birmingham and Oxford Junction Railway, up to the completion of the great viaduct, and the suspension of the works in 1849.

The town of Birmingham stands upon a series of eminences and interlying valleys, of the new red sandstone formation, so that some considerable works, both of viaduct and tunnelling, are necessary on the lines of railway carried across the district. The original town was in the vicinity of High Street and St. Martin's Church, with a flat alluvial plain lying between it and the river Rea, in the district now occupied by Smithfield and Bradford Street. The encroachments of furnace refuse, and other rubbish, from time to time, may perhaps account for the water-course no longer occupying the lowest point of the valley, and its being pushed off the gravel, on to the edge of the red marl.

The Birmingham Extension commences at a point near the Coventry Road, and was intended to terminate, by a junction with the Birmingham, Wolverhampton, and Dudley Railway, at Great Charles Street. From Adderley Street to Park Street, both inclusive, the town is crossed by a viaduct, and the necessity for passing over these streets at a considerable elevation, caused the great height of its intervening portion. From Moor Street to Monmouth Street, the line passes under the highest of the hills on which the town is built. This was proposed to be by a tunnel, the greatest portion of which would have been constructed as a covered way, that is, by opening the ground, putting in the brickwork, and again covering up; and the part of it as yet completed, from Moor Street to High Street, about 142 yards in length, was executed in this manner.

In September, 1846, a tracing and survey of the district of the town through which the railway was intended to pass, was carefully made; and shafts were sunk, at several places along the line, for the purpose of ascertaining the nature of the strata, which were found to consist, in the highest ground of red sand, and in the valley, of red and mottled marl, with, in some places, an overlying bed of gravel. The winter of 1846-7 was occupied in the various preliminaries.

A contract was ultimately entered into with Messrs. Branson and Gwyther, of Birmingham, and the first brick of the viaduct was laid on the 3rd of March, 1847, in the east pier of the arch over Trent Street.

The viaduct consists of fifty-seven openings, composed of—

	Span.	Rise.	Angle of Skew.	Amount of settlement of Arch in parts of the Span.
	Ft. In.	Ft. In.	Degrees.	
Nine segments, each	30 0	6 0	..	..
Seven semi-ellipses, each	37 0	15 0	..	..
Twelve ditto	45 0	15 0	..	..
One ditto	48 0	15 0	..	..
Seven ditto	43 8	15 0	..	..
Fifteen semi-circles, each	30 0	15 0	..	..
Park Street, girder bridge	36 0	..	9	..
Allison Street, segmental arch . .	46 6	6 0	9	387
Meriden Street, semi-elliptical arch.	43 1	15 0	3½	308
Oxford Street, ditto	58 0	15 0	12	388
Floodgate Street, ditto	48 0	15 0	13	386
Adderley Street, segmental arch .	44 0	7 6	10	..

Its total length is 930 yards, the general width, from face to face, is 31 feet 7½ inches, and the width between the parapets, at the level of the rails, is 29 feet. The line is level from Adderley Street to Allison Street, rises 2 feet from the latter street to Park Street, and falls again to its original level near the mouth of the tunnel.

The street bridges consist, in general, of three openings, and the arches in their abutments are of different spans at each end, in order that the succeeding piers may be at right angles to the centre line of the railway.

The viaduct is entirely built of brickwork in mortar, with the exception of the soffit of the bridge over Park Street, which is constructed of cast-iron girders, with a cross transomed Memel flooring. The red brick of the district was used throughout the footings, the internal work of the piers, and the spandrill walls. The arches and parapets were constructed of Staffordshire brick from the "common stock," the copings, mouldings, and dentals, being made of Staffordshire brick clay, and the whole of the work is faced with Staffordshire "best blue." The middle pillar of each pier was also, at first, built entirely of Staffordshire brick up to the springing line; but, subsequently, all the pillars were built of this material, for the first 6 feet above the footings. All the brickwork was set in moist mortar, so as by pressure to obtain thin joints, and in hot weather

the bricks were kept constantly wet. From some experiments on the relative weights of the bricks of the district, when completely dry, after being kept near a fire for twenty-four hours, and when thoroughly saturated by immersion under water for twenty-four hours, it appeared that the average percentage of increase was 10·75, proving that the weight of a mass of brickwork may become so greatly increased, as, under some circumstances, to endanger the safety of a foundation.

The mortar used in the work was composed of the red sand of the locality, and of either Dudley lime, or of Greaves' blue lias lime—the latter being used in all the foundations, arches, and face-work—mixed in the proportions of one part of slaked lime to two parts of sand. The lime was slaked in large heaps, then covered with sand, and used after 24 hours, or 36 hours. Some experiments were made with large quantities of this lime, to ascertain the relation between the bulks before and after slaking. It was measured in a basket, as taken from the kiln, and was re-measured in the same basket, after being slaked, when the following result was obtained:—

—	Fresh.	Slaked.
Greaves' blue lias	1	1·775
Dudley	1	2·2

All the mortar was worked by a steam mill, the rollers of which were each $1\frac{1}{2}$ ton weight, and was capable of supplying fifty bricklayers per day, with mortar of a perfectly even texture, entirely free from lumps, and therefore less likely to become vesicular, from the transfiltration of water, than that mixed by the common pug-mill. This mill was driven by a 4-H.P. engine, made by Mr. Nathan Gough (Assoc. Inst. C.E.), of Manchester, and was erected in a shed near Oxford Street. Pieces of this mortar, from one to two years' old, taken from the works on various occasions, were submitted to the same tests as the bricks, for ascertaining the relative weights when dry and wet, when it was found that the average percentage of increase was about 21.

A piece of sandstone, taken from a cutting at Shrewley, on the main line of the Birmingham and Oxford Junction Railway, the material of which the Tower of St. Mary's, at Warwick, is constructed, having been similarly tested, was found to have increased 6·3 per cent.

For the purpose of further testing the qualities of the mortar, in October, 1848, several small vessels were made, by moulding fresh

lias mortar, about 1 inch in thickness, over the outside of a common earthenware quart bowl, so as to form a similar figure. These mortar bowls were placed in a frame, and exposed to the open air, but excluded from sun and rain; they were immediately filled with water, which passed through slowly, and was replenished daily for two months, when a small stalactite, in no case more than half an inch long, was soon formed. The bowls were then left to get dry, by the combined action of filtration and evaporation, which took from two to three months, between December, 1848, and March, 1849. On being refilled, and kept full until the end of August, 1849, no water filtered through, at least not in sufficient quantity to drop, and the mortar became so hard, as, when struck, to ring almost like china.

From these observations it may be concluded, that lias lime and the red sand of Birmingham form a mortar, which is a true chemical compound; and that any overdose of lime, being only in the state of mechanical mixture, may be removed by the action of water. The mortar in the foundations of the houses which were removed during the progress of the works, was frequently found to be very hard and well set, although obviously very badly worked, being full of lumps of white (Dudley?) lime; and the question has since suggested itself, whether the red sand of Birmingham has any properties similar to those of the *arènes* of M. Vicat?*

The setting of the centres was commenced in May, 1847; five ribs constituted a set, each rib being supported on two vertical and two sloping props, the former under the heels of the ribs, and the latter under the points, where the struts of the ribs terminated in an iron shoe. The lower ends of all the props were supported by a cill piece, resting on five brick piers carried up from the footings, a pair of hard wood wedges being interposed between the cill and the foot of each sloping prop. At the level of the springing, the vertical props were again similarly connected, and, in every instance, two hard wood wedges were inserted between the cill and the heel of each rib. The laggings used were deals, 3 inches in thickness, carefully dressed by the adze to the proper curve, and lined for the courses of the skew arches. The abutment arches being of different spans at each end, were built with square courses, for a certain distance from the right-angled abutment, and skew from the other, so as to meet with a straight key. The contractors exercised a wise

* Vide, "A Practical and Scientific Treatise on Calcareous Mortars and Cements, Artificial and Natural." By L. J. Vicat. Translated, with the addition of explanatory notes, by Capt. J. T. Smith, M.E. 8vo. Plates. London, 1837. Notes to chap. vii., arts. 34 and 34.

liberality in preparing eight sets of centres for the large arches, so that Oxford Street, its two abutments, and five other arches, east from it, were centered at the same time. These were sufficient for the thirteen arches, up to Floodgate Street, and they were afterwards altered to fit the arches of 43 feet 8 inches span, east of the river Rea. Four sets of centres were provided for the seven elliptical arches of 37 feet span, between Allison Street and Oxford Street, besides a set of 43 feet 1 inch span, for Meriden Street.

The work was commenced, as before stated, at Trent Street, and carried on in both directions; towards the tunnel in a straight line, and in the other direction on a curve to the eastward of 120 chains radius. This curve required, either that the arches should be slightly conical, or that the piers should be made thicker on the convex side. The latter alternative was considered preferable, both on account of stability, and because it allowed the ribs of the centres to be used indiscriminately. The piers for the arch over the river Rea were set out in May, 1847, whilst the ground between that and the other part of the work was still covered with houses, so that the intervening length on the curve had to be carefully measured, and the subsequent filling-in proved the correctness with which this operation had been performed.

The spandrill walls, next the face walls, were built with a batter of 1 in 10 inwards, and two iron tie rods were introduced at the level of the springing of the outside spandrill arches, so as to take the thrust from the face walls. The tie rods were of scrap iron, each 2 inches by $\frac{1}{4}$ inch in section, keyed at each end through iron plates about 10 inches square, one being built into the face wall, and the other being flush with the inner side of the battered spandrill. Corbels of heading bricks were carried out from the backs of the arches in the range of the spandrill walls, of the same width with them, and connected by a brick beam from arch to arch, for stiffening and equalizing the pressure from end to end of the viaduct.* Pieces of hoop iron, each about 3 feet long, were laid diagonally across the bed joints of the arches into which the corbels were bonded; another course of brickwork was then added, and a second row of hoop iron was laid in the reverse position. Two rows of hoop iron, 12 inches apart, at right angles to each other, were also inserted at the tops of the pillars of the piers.

The settlement of the arches was taken by a spirit-level from three nails, which were driven into each face of the arch before the

* This mode of construction was suggested by something very analogous in Blackfriars Bridge, and its useful effect may be judged of, from the comparatively small amount of the settlement of the arches.

centres were slacked; one of the nails was placed in the crown of the arch, and the two others at 12 feet on each side. The levels were taken before the centres were slacked, and again when the laggings had been for a considerable time quite clear of the soffit. Upon two of the elliptic arches of 45 feet span, east of Oxford Street, three straight lines were drawn, in order to observe the curves with a point of inflexion, noticed by Perronet at the bridges of Neuilly and Nogent, but from the small amount of settlement no appreciable change in the form of the lines could be detected. The crowns of the arches of the bridge at Neuilly are stated to have sunk 23 inches!* a dangerous amount, if the centres were slacked so suddenly as to cause any appreciable dynamical shock, however such settlement might be compatible with a sound state of the arch, if slowly let down. Great care was therefore taken in slacking the centres, the ribs being eased singly, and a mark made on each pair of wedges, so that each rib should be slacked to the same amount.

On the completion of the viaduct, the roadway was ballasted to the depth of 1 foot, with the red sandstone rock, from the cutting of the London and North Western Birmingham Extension, at the place where it passes under the extension of the Birmingham and Oxford Junction Railway, between Park Street and Moor Street. The rock at this point was blasted, and a few observations were carefully made, in order to ascertain the expenditure of labour and of gunpowder per cubic yard; when it was found that each man, in a day of 10 hours, removed $27\frac{1}{2}$ cubic yards, at an expenditure of $2\frac{1}{2}$ pints of gunpowder.

A brief description will now be given of the different works, and more detailed particulars may be obtained from the Appendix and Drawings accompanying this Paper, to which reference is made.

Park Street Bridge has brick abutments, the soffit being formed of fourteen cast-iron girders (made by Messrs. Thompson and Astbury, of Smethwick), bolted together in pairs, with a balk between each pair; the girders rest upon an oak wall plate, 6 inches by 12 inches scantling. The flooring is made of balks, of Memel timber, 9 inches square. All the timber-work was creosoted. The parapets, the height of which was fixed by the Act, are formed of corrugated iron, No. 14 Birmingham wire gauge, attached to cast-iron girders at the top and bottom. The pilasters over the abutments are of brick, with Derbyshire stone mouldings. This bridge was constructed of a sufficient width for three lines of rails, and the viaduct was again reduced to its general width, of 31 feet $7\frac{1}{2}$ inches from face to face

* Vide Weale's "Bridges," vol. ii. p. 168.

at Allison Street, by means of double, or S, curves of 600 feet radius, so that the lengths of the intervening piers of the brick arches of 30 feet span required to be gradually diminished. Each of the girders was tested *in situ*, by suspending a weight of $18\frac{1}{2}$ tons of rails from the centre, when the average deflection was found to be $1\cdot22$ of an inch, and the permanent set $0\cdot13$ of an inch. The deflections were measured from a fine copper wire, strained below the girder. The weights were removed in a few minutes, and the permanent set was the deviation which each girder exhibited as soon as the weight was removed. Estimating the weight of the timber roadway and the ballast, and adding one ton per lineal foot for the load, the greatest statical strain to which this bridge could be exposed, would not exceed 13 tons on the centre of each single girder, or about one-fifth of the breaking weight, calculated from the formula $\frac{26ad}{L}$.*

Allison Street Bridge consists of one arch over the street of 46 feet 6 inches span, 6 feet rise, and 9° skew, and two very flat segmental arches in the abutments. The western foundation of this bridge being wet, owing to land springs, its whole area was covered with two courses of brickwork, before commencing the footings. The arches were built with a one and a half brick ring next the soffit, bonding courses, or headers, being frequently introduced.

Meriden Street Bridge consists of a semi-elliptic arch, over the street, 43 feet 1 inch span, 15 feet 6 inches rise, and $3\frac{1}{2}^\circ$ skew, and of semi-elliptic conical arches in the abutments. The adjoining arches, at each end, are semi-ellipses of 37 feet span, and 15 feet rise. Flues were formed in the outside columns of the piers, where the thickness was not less than 6 feet; half-brick openings, were, in all cases, left between these flues, and the spaces above, between the spandrill walls.

Oxford Street Bridge consists of three arches:—the middle one, over the street, of 58 feet span, 15 feet rise, and 12° skew, and two abutment arches, which are portions of the surface of a cone on an elliptic base, of 40 feet span, along the centre line. These arches are bonded into the abutments, which are sufficiently strong to enable this bridge to stand by itself, in case of accident to any of the adjacent arches. The centre arch was laid in courses of alternate headers and stretchers, and the back of this arch, as of all the other street bridges was asphalted, after the spandrills were built.

From Oxford Street to Floodgate Street, the viaduct consists of thirteen arches,—twelve of 45 feet span, and one of 48 feet span,—

* Tredgold on Cast Iron, part ii. p. 446.

the average depth from the line of rails to the bottom of the foundations being 58 feet. The footings consist of twenty-four courses of brickwork, reduced by one-quarter brick offsets, to the width of 8 feet 6 inches at the neat work, and the piers are all gradually reduced to 8 feet, at the level of the springing. The foundations were all carried down to the red marl, and estimating the weight of the brickwork at $1\frac{1}{2}$ ton per cubic yard, the greatest pressure on any foundation does not exceed 2 tons per superficial foot. The greatest pressure to which the brickwork is exposed, is probably at the top of the footing of the west pier of Trent Street Bridge, where it is about 7 tons per superficial foot.

The south elevation of Floodgate Street Bridge was carried forward, from the general line of the viaduct, for the sake of architectural effect.

The arches east from Floodgate Street to Heath Mill Lane inclusive, are 43 feet 8 inches span, but are, in all other respects, similar to those westward. The river Rea passes through the second arch east from Floodgate Street: the foundations of this arch were carried into the red marl, to a depth of 62 feet 9 inches below the level of the rails. From Heath Mill Lane to Adderley Street, the arches being reduced to 30 feet span and the piers to 4 feet 6 inches thick, the recesses and dentals are omitted, and the parapet is one foot lower, than over the other parts.

Adderley Street Bridge is the eastern termination of the viaduct, an embankment being formed against it; the west abutment of this bridge is strengthened by the addition of longitudinal arched counterforts.

During the progress of the works, accounts were kept of the amount of labour, under all the various forms of its application; but more especially in order to obtain a fair average, for the amount of work done in each day by each bricklayer, and also to establish the amount of assistant labour required to produce the greatest efficiency, when the following results were obtained:—

—	Bricklayer.	Labourer.	Built.	
In 1847	1	1·44	Cubic yds. 2·39	
In 1848	1	1·10	2·33	

The reason of the quantity of work per man per day being greater in the first year, was owing to the foundations forming a large proportion of that year's work, the arches and parapets being principally executed in the second year. The assistant labour is less in the

second year, the material being then almost entirely raised by lifts, hereafter to be described.

The Tunnel is 27 feet in width at the level of the rails, and the portion completed is 142 yards in length. It is built of Staffordshire brick set in mortar, excepting the arch lengths through Carr's Lane, which were set in cement, as the work had to be pushed on with rapidity at this point, in order to make the temporary stoppage of the thoroughfare as short as possible, and also to lessen the danger to the houses on each side. Recesses, or man-holes, of 4 feet wide were left in the side walls of the tunnel, at distances of 40 feet from centre to centre. The average rate of progress in the tunnel was 8.1 lineal yards per week, from August to November 1847; for the fortnight ending October the 1st, 25½ lineal yards were completed, being at the rate of 2.125 lineal yards per working day; the maximum of 3 lineal yards, in 24 hours, which comprised about 250 cubic yards of excavation, and 60 cubic yards of brickwork, was reached at the point of passing the corner of Carr's Lane Chapel. The end of the brick arch is on the west side of Moor Street, and the bridge under that street constitutes a portion of the tunnel. This bridge consists of brick abutments, cast-iron girders, and a timber floor, being in every respect similar to the bridge over Park Street, excepting that the span is only 30 feet 4 inches: each of the girders was tested by suspending a weight of 16 tons from the centre. The east parapet, which is over the tunnel mouth, is of corrugated iron, 18 feet high, surmounted by an oak moulding, instead of a cast-iron girder, as at Park Street. The gradient through the tunnel rises towards Monmouth Street, at the rate of 1 in 45½. During the period of constructing the works, the culverts for the Birmingham sewerage were simultaneously carried under the tunnel, in the line of Carr's Lane, and also of Moor Street.

In the course of the erection of so extensive a work, which involved the raising of great weights of material to a considerable height, the economy of the means for accomplishing this, became, of course, a very important item in the cost of construction. It is now proposed to describe the various modes adopted, and the mechanical contrivances used, for that purpose, and to deduce from a long series of observations, values for the useful effect produced by the "Labouring Force,"* ("Travail Mécanique,"†) of a man,

* Vide "The Mechanics of Engineering." By the Rev. W. Whewell, D.D. 8vo. Cuts. Cambridge, 1841. Sec. 155.

† Vide "Introduction à la Mécanique Industrielle, physique ou expérimentale." By J. V. Poncelet. 8vo. 2nd edition. Plates. Metz, 1841. Page 62, sec. 77, *et seq.*

under different modes of its application ; as also for a horse, under alternating motion over a short space.

These observations were made over a considerable portion of time, in the years 1847 and 1848, in order that the disturbing causes, arising from change of weather, difference of season, and variety of workmen, should be eliminated, and the mean effort * of the labouring force of an ordinary English workman be obtained. An observation was commenced at any convenient time, and was continued for a certain number of hours, more or less, the number of trips taken during the time of the experiment being registered, and the amount of material raised being ascertained, by counting the bricks, and measuring the mortar in the box in which it was lifted. The number of men employed to work each lift, the mode in which their labour was applied, and the duration of its application were also classified. From these several elements the useful effect, or profitable horse-power, above the resistances of friction, in lbs. by feet per minute, was calculated. In the calculations the weight of thirteen bricks was taken at 1 cwt., which is slightly above that of the Staffordshire "brown" brick, when thoroughly dry, but considerably under what it is, when saturated with water ; the largest proportion of the bricks raised by the lifts, being for the arches and parapets, consisted of Staffordshire "brown" and "blue." The mortar was found, from several trials, to weigh from 112 lbs. to 120 lbs. per cubic foot, according to its age ; it was therefore taken at 112 lbs. per cubic foot. The ballast was taken from one trial at 112 lbs. per cubic foot ; it consisted of old brick rubbish mixed with gravel. The labour of a boy was estimated at half that of a man, which is about what it would represent in wages.

The Horse Run Lift, in which considerable loss must take place, from the frequent stopping and reversing, was worked by alternate motion, the full and empty barrow, or box, alternately ascending and descending. The barrows were filled by men below, and then hooked to the chain ; they were caught above, landed, and wheeled clear of the top stage, and the "empty" hooked on. Two of these lifts were erected ; one close to the east side of Meriden Street, the other on the east bank of the river Rea.

The Swing Lift consisted of a balk fixed vertically in the ground, in such a position, that the ends of a long lever by which it was surmounted, could be alternately swung round to the same stage. The lever was constructed of a strong timber, trussed by means of an

* Vide Introduction à la Mécanique Industrielle, sec. 73, page 58, *et seq.*

iron rod, strained over a short king post of hard-wood. The lever was balanced on its centre by an iron sling, and was free to move in a horizontal plane, by means of a strong iron pivot, working in a cup on the top of the vertical balk. Each end of the lever had an iron hook, to which the barrows containing the materials and the counterpoise, and ropes by means of which the men below guided the loads to their proper destination were attached. The men, called "riders," descended by their gravity in the empty barrow, thereby lifting the weight at the other extremity of the lever; and ascended again by ladders without carrying up any material.

The box lift consisted of four upright beams, connected at the top by cross braces; a wheel was carried by these braces, and round it was passed a rope, at each end of which a box was attached. The material was raised in each of the boxes alternately, by the weight of men descending in the other.

The observations furnish the means of, at once, contrasting the cost of raising material, either by the different lifts, or by the same lift, when working with a different velocity, or the application of a different amount of power; and it may sometimes be convenient, in making such comparisons, to adopt a general expression for cost, rather than a money price, which varies from time to time, and in different places, according to the ordinary laws of supply and demand.

Let it be required, for instance, to find the relative cost of raising by the Horse Run Lift. The mean calculated efficiency, in the third series of experiments, was 18·060 lbs. by feet per minute. Now taking the working day at 10 hours, or 600 minutes, the day's efficiency will be $\frac{18060 \times 600}{46 \times 2240} = 105$ tons raised 46 feet high, pro-

duced by the labouring force of 7 men and 1 horse. Let m represent the daily wages of a man, h (= about $2m$ at the time and place of observation) that of a horse; then $9m$ = cost of raising 105 tons 46 feet high, or $\frac{9}{105} m = \cdot0857 m$ = cost per ton. Again, the

mean calculated efficiency, in the second series of experiments, was 14·646 lbs. by feet per minute. Now this gives as the day's efficiency $\frac{14646 \times 600}{46 \times 2240} = 85$ tons raised 46 feet high, produced by $6\frac{1}{2}$ men

and 1 horse. Therefore $8\frac{1}{2} m$ = cost of raising 85 tons 46 feet high, or $\frac{8\cdot5}{85} m = \cdot10 m$ = cost per ton. Taking now the mean

calculated efficiency, in the first series of experiments, the day's

efficiency will be $\frac{16848 \times 600}{42 \times 2240} = 103\frac{1}{2}$ tons raised 42 feet high, by

7 men and 1 horse. Therefore $9m$ = cost of raising 103.5 tons 42 feet high, or reducing this to what it would be if raised 46 feet high, $9m$ = cost of raising $94\frac{1}{2}$ tons 46 feet high, or

$\frac{9}{94.5}m = .095m$ = cost per ton. The relative cost of working in these three cases is consequently .0857, .10, and .095; and taking m , which represents the daily wages of a man, at three shillings, the several prices per ton will be 3.08, 3.6, and 3.4 pence.

With the Swing Lift the mean calculated efficiency was 10.46 lbs. by feet per minute, and following the same process of calculation,

$\frac{1046 \times 600}{47.5 \times 2240} = 6$ tons nearly, raised $47\frac{1}{2}$ feet high, by 10 men.

Therefore $\frac{1}{6}m = .166m$ = cost per ton raised $47\frac{1}{2}$ feet, = 6 pence

per ton, if the value of m is taken at three shillings, or, about 5.9 pence per ton, when the height is reduced to 46 feet, as in the former instances.

With the Box Lift the mean calculated efficiency was 15.10 lbs. by feet per minute; therefore the cost of raising by this machine

will be obtained from the formula $\frac{1510 \times 600}{41 \times 2240} = 9.86$ tons raised

41 feet high; or, when reduced to 46 feet = 8.8 tons. And

$\frac{1}{8.8}m = .114m$ = cost per ton, = 4.13 pence, when the value of m is taken at three shillings.

The relative cost, then, of raising material to the height of 46 feet by these three methods,—the horse lift, the swing lift, and the box lift,—is 3.08, 5.90, and 4.13 pence per ton respectively; showing a saving, in favour of the horse lift against the swing lift, of nearly 3 pence per ton, and against the box lift of rather above 1 penny per ton.

The proper number of men to be employed, in order to obtain the maximum effect from either of these machines, depending upon the height, upon the magnitude of the load to be put in below, and taken out above, and the kind of material, involves considerations with regard to the size of the box, the weight of the counterpoise, and other points, which can only, in every case, be accurately determined by experiment.

A machine, similar to the box lift, is described by M. Poncelet,* from which it appears, taking the word "journallement" to mean 10 hours, that the amount obtained was 3394 lbs. by feet per minute, which nearly agrees with an observation, where the machine was worked by one man, and this man ascended unloaded.

Some observations were made on the amount raised by hod-men working in the usual way, that is, descending by a ladder, and the result was 520 lbs. $\times$ feet per minute. The value obtained is the nett effect, and the units of work consumed in raising the hod must, in both cases, be added, in order to obtain the gross effect. As the weight of a hod may be taken at 10 lbs., the gross effect from this table will be $520 + 60 \{10 \times 6 \text{ feet (velocity under load)}\} = 580$ lbs. by feet per minute; with the box lift, the gross effect was $857 + 142 \{10 \times 14\frac{1}{2} \text{ (velocity)}\} = 999$ lbs. by feet per minute. The great difference between these values shows, that the hod-men in one case were working very much below the proper amount, and this comparison points out the necessity for employing active foremen to superintend the labour on a large work. The regularity of the box lift, induced corresponding regularity in the movement of the hod-men, who acted as descending weights. It may be also worthy of mention, that part of the work recorded, was done under the immediate superintendence of the sub-contractor himself; whilst that stated above, for hod-men, was done as day-work, just before the conclusion of the works of the viaduct. The value obtained for hod-men's work with the box lift, contrasted with that given by M. Poncelet, for nearly similar circumstances, shows the useful effect of the French labourer to be 1128 lbs. by feet per minute for 6 hours—that of the English labourer to be 999 lbs. by feet per minute for 10 hours, or 193.320 units of work in favour of the English labourer; and it should be stated, that in

* Vide "Introduction à la Mécanique Industrielle, physique ou expérimentale." By J. V. Poncelet. 8vo. 2nd edition. Plates. Metz, 1841. Page 237, sec. 208. "De la meilleure manière d'utiliser la force de l'homme dans l'industrie." "Parmi les mécanismes imaginés dans la vue de remplir cet objet, le plus simple est celui qui a été mis en usage, par M. le Capitaine du génie Coignet, aux travaux de terrassements du fort de Vincennes, près de Paris: il consiste dans l'emploi d'une corde passant sur une grande poulie, et armée, à ses extrémités, de deux plateaux dont l'un porte l'homme et l'autre le poids à monter. Ces travaux, dans lesquels chaque manœuvre a élevé 'journallement' 310 fois, à la hauteur de 13 m, le poids de son corps (70 kilog. environ), en gravissant de simples échelles, ont confirmé, de la manière la plus authentique, les avantages inhérens, à ce mode d'employer la force de l'homme, par les économies considérables de main-d'œuvre qui en ont été la conséquence depuis plusieurs campagnes."

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the former instance, the workmen ascended by means of steps, and not by a ladder, as was the case with the English labourers, which must be the most fatiguing of the two.*

The communication is accompanied by a very elaborate series of tables on the absorption of water by bricks, by mortar, and by Shrewley sand-stone,—of the settlements of the arches of the street bridges,—of the work performed by the various lifts, under different circumstances, with the concurrent particulars,—and that by ordinary workmen; and is illustrated by a series of ten drawings of all the bridges and works, for which the isometric projection has been adopted, and the sections have been so taken, that every dimension may be obtained; orthographic sections of details being added, in some cases, in order to render the various parts more distinct. These drawings (Nos. 4563 to 4572) were made by the Author's pupils, of the first year, in the Engineering class of Queen's College, Cork.

December 16, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

The first part of a Paper was read, "On the Alluvial Formations, and the Local Changes, of the South-Eastern Coast of England," by Mr. J. B. Redman; but, as the reading of the second part was adjourned until the 20th January, 1852, the Paper is given entire at that date.

* Vide "Introduction à la Mécanique Industrielle, physique ou expérimentale." By J. V. Poncelet, 8vo. 2nd edition. Plates. Metz, 1841. Page 234, sec. 205.

"Tableau des quantités de travail journalière que peuvent fournir les moteurs animés dans différentes circonstances."

Nature du Travail.	Poids élevé ou effort exercé.	Vitesse ou Chemin par Seconde.	Travail par Seconde.	Durée du Travail Journalier.	Quantité de Travail Journalière.	English Measure.
<i>Élévation vert. des poids.</i>	Kilog.	Mètres.	k × m	Heures.	k × m	Feet × lbs.
Un manœuvre élevant des poids, en les portant sur son dos au haut d'une rampe douce, ou d'un escalier, et revenant à vide . . .	65	0·04	2·6	6	56160	406·037†

† The French kilometre being equal to 7·233 lbs × feet, or the English dynamical unit equals 1128 lbs. × feet per minute.

ANNUAL GENERAL MEETING.

December 23, 1851.

SIR WILLIAM CUBITT, President, in the Chair.

Messrs. A. Ogilvie, J. W. Bazalgette, and G. Donaldson, were requested to act as Scrutineers of the Ballot for the election of the President, Vice-Presidents, and other Members and Associates of Council for the ensuing year.

The list of the attendances of the Members of Council for the past year was read, and the Ballot was commenced ; the balloting papers being sent for examination at intervals of fifteen minutes, in order to expedite the labours of the Scrutineers.

The Annual Report of the Council on the proceedings of the Institution during the past year was read.

Resolved,—That the Report of the Council be received and approved ; and that it be referred to the Council to be printed and circulated with the Minutes of Proceedings, in the usual manner.

The Telford Medals and Premiums, and the Council Premiums, which had been awarded, were presented.

Resolved,—That the thanks of the Meeting are due, and are presented to Messrs. Swann and Appold, for the readiness with which they undertook the office of Auditors of Accounts, and for the clear balance sheet they have laid before the Meeting ; and that Messrs. Appold and Pole be requested to undertake the office of Auditors of Accounts for the ensuing year.

Mr. Swann returned thanks.

Resolved,—That the thanks of the Meeting are justly due, and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Simpson, *V.P.*, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Sir William Cubitt, President, for his strenuous efforts in the interest of the Institution, for his great attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Sir William Cubitt, President, having left the Chair, returned thanks, and addressed the Meeting on giving up the post of President.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Charles Manby, the Secretary, for his constant zeal and attention to the interests of the Institution, the ability displayed by him in the execution of his duties, and his attention to the individual wishes of the Members.

The Secretary returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected to fill the several offices in the Council for the ensuing year :—

President,

JAMES MEADOWS RENDEL.

Vice-Presidents,

Isambart K. Brunel,
Joseph Locke, M.P.,

James Simpson,
Robert Stephenson, M.P.

Other Members of Council.

Members,

George P. Bidder,
Joseph Cubitt,
John E. Errington,
John Fowler,
Charles H. Gregory,

John Hawkshaw,
John R. McClean,
Charles May,
Joseph Miller,
John Scott Russell.

Associates,

John G. Appold,

Edward L. Betts.

Resolved,—That the thanks of the Meeting be given to Messrs. A. Ogilvie, J. W. Bazalgette, and G. Donaldson, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office, and that the ballot papers be destroyed.

ANNUAL REPORT.

1851-52.

THE period has again arrived, when the Council must lay down the temporary authority with which you invested them, and in doing so, they would express a hope, that the dignity of the Institution has not been lessened, nor its sphere of usefulness circumscribed, during their tenure of office.

The year 1851 will always be regarded as remarkable, from its being that of the Great Exhibition of the Works of Industry of All Nations ; and this memorable gathering of the sons of industry and votaries of pleasure, so fully absorbed the attention of the world, that scientific societies, only presenting their usual features, ceased to be attractive, even to their steadiest adherents.

This Institution, although not taking any ostensibly-active part, as a body, contributed essentially to the success of the undertaking, by the individual exertions of the members of all classes. Among the competitors, whose plans were exhibited in this room, were many names well known here ; the suggestions for the mode of providing the guarantee fund for the erection of the building, as well as many other points in connexion with the classification, &c., emanated from hence ; amidst the Royal Commissioners, the Building Committee, their executive staff, and the Jurors, some of our best men were prominently useful ; the designer of the present building and those whose energies were so successfully devoted to the task of its construction, also belong to us, whilst "the weight of responsibility, the arduous duty of supervision, the honour of acting as the master mind, to weigh the requisites, to determine the design, and to govern the construction," were reserved for Sir William Cubitt, the President, who as long ago as previous to the nomination of the Royal Commissioners, in December 1849, had been particularly designated, by our late honorary Member Sir Robert Peel, for the onerous duties which devolved on him.

This "World's Fair," as it has been happily termed, attracted to it most of the celebrated men of science and art, as well as the producers and manufacturers of all nations, and from peculiar circumstances, this Institution became the centre, to which most of the professional visitors were directed, and from hence, it is believed, that few departed, without receiving the assistance, or information they sought ; and the Council would embrace this opportunity, of offering their thanks to those gentlemen, whether Members, or not,

who so kindly honoured the letters of introduction of the Secretary, as to win from all to whom they were given, glowing accounts of their reception, warm offers of similar services to our Members on their visiting foreign countries, and in many instances, presents of books for the library, from those who had been admitted to its privileges, during their sojourn here. It is confidently hoped, that the relations with foreign countries, so pleasantly commenced, may become more intimate, and that collective and individual benefit may be the result.

The Council have great pleasure in recording a munificent act of his Grace the Duke of Northumberland, who caused to be notified to the Institution, through Mr. Decimus Burton, that cards of admission to his princely mansion might be distributed by your Secretary, who was, accordingly, amply supplied with them.

Amidst the excitement of such a period, it is not surprising, that only a small number of original communications should have been presented; indeed, on several occasions, the discussions alone prevented the Meetings from being almost profitless. It is hoped, however, that during the present Session the numerous topics suggested by the assemblage of models and specimens, from all parts of the world, will induce the production of many interesting papers; and in furtherance of this, the list of subjects for Premiums has been altered and extended, and the attention of many of the best authorities on the various topics, has been directed to the list, with a pressing request for communications from them; in several instances, favourable replies have been given, and many more are confidently expected.

The principal papers read during the past Session were, "On the Explosions in Coal-mines," by W. West; "On the Ventilation of Collieries," by W. P. Struvé; "On the Construction of the Exhibition Building," by M. D. Wyatt; "On Patent Law Protection," by A. V. Newton; "Description of the 'Royal Border' Bridge," by G. B. Bruce; "On the Mode of Working the Oldham Incline," by Captain J. M. Laws, R.N.; "Account of the Sea Walls at Penmaen Mawr," by H. Swiuburne; "On the Newry Navigation," by Sir J. Rennie; "Description of the Lockwood Viaduct, on the Huddersfield and Sheffield Railway," by J. Hawkshaw; "On the 'Nominal Horse-power' of Steam-engines," by Commander L. G. Heath, R.N.; "On Natural and Artificial Foundations," by S. Clegg, Jun.; "On the Demonstration of the Rotation of the Earth by means of 'Two Pendulums,'" by Homersham Cox; "On Gauging Streams," by J. Leslie; "On the Discharge of Water by Overfalls, or Weirs," by T. E. Blackwell; "On the Foundations of

chester Bridge," by J. Hughes; "On the Isthmus of Suez, and the Ancient Canals of Egypt," by J. Glynn.

To a select number of these papers, Telford Medals and Council Premiums of Books, have been awarded:—

A Telford Medal, in Silver, to Samuel Clegg, Jun., M. Inst. C.E., for his Paper "On Foundations, Natural and Artificial."

A Telford Medal, in Silver, to Matthew Digby Wyatt, Assoc. Inst. C.E., for his Paper "On the Construction of the Building for the Exhibition of the Works of Industry of All Nations in 1851."

A Telford Medal, in Silver, to Henry Swinburne, for his Paper, "An Account of the Sea Walls at Penmaen Mawr, on the line of the Chester and Holyhead Railway."

A Telford Medal, in Silver, to George Barclay Bruce, M. Inst. C.E., for his Paper, "A Description of the Bridge built over the River Tweed, on the line of the York, Newcastle, and Berwick Railway."

A Telford Medal, in Silver, to John Hughes, Assoc. Inst. C.E., for his Paper "On the Pneumatic Method adopted in constructing the Foundations of the new Bridge across the Medway, at Rochester."

A Telford Medal, in Silver, to William Price Struvé, M. Inst. C.E., for his Paper "On the Ventilation of Collieries, Theoretically and Practically considered."

A Telford Medal, in Silver, to Alfred Vincent Newton, for his Paper, "An inquiry into the nature of Patent Law Protection, with a view to the better appreciation and security of the Inventor's rights."

A Council Premium of Books, suitably bound and inscribed, to Joseph Glynn, M. Inst. C.E., for his Paper "On the Isthmus of Suez, and the Canals of Egypt."

A Council Premium of Books, suitably bound and inscribed, to Thomas Evans Blackwell, M. Inst. C.E., for his Paper, "Results of a series of Practical Experiments on the Discharge of Water by Overfalls."

A Council Premium of Books, suitably bound and inscribed, to James Leslie, M. Inst. C.E., for his Paper, "Proposal for a mode of Computation, whereby Floodwater may be excluded from a set of Gaugings."

A Council Premium of Books, suitably bound and inscribed, to Henry Carr, Assoc. Inst. C.E., for the Drawings illustrating his Paper, "Description of two Bridges over the River Don and Canal, &c., at Sprotbro', near Doncaster."

These communications were so fully discussed, when they were read, that the manner in which the authors treated the subjects must be familiar to all who attended the Meetings.

The papers by the late Mr. West and Mr. Struvé, although relating to the same subject, were essentially different, the former being chiefly a record of the results of explosions in mines, and the latter showing the necessity for more perfect ventilation, and the means of effecting it, in order to prevent, as much as possible, the recurrence of such explosions. The decease of Mr. West prevented that notice of his paper, by the Premium Committee, which it would otherwise have received, but to Mr. Struvé's useful paper a Telford Medal was awarded.

Mr. Wyatt's account of the construction of the Exhibition Building, was extremely interesting, not only for its clear description of a building of peculiar character, destined for a special purpose, and erected in an incredibly short time, but because the opinions elicited, during the discussion, must have tended, in some degree, to the suggestion of those measures of precaution, by which the public apprehensions were so successfully allayed. In this discussion, our Associate, Mr. Turner, who from the commencement had taken so much interest in the question, brought forward his designs, of which, though they were not adopted, it is but fair to say, that as examples of constructive ability, and of tasteful combination of materials, they will bear a very favourable comparison with the actual building.

The Newry Navigation, so well described by Sir John Rennie, was shown to possess peculiar features of interest, not only to the professional man, but to the statician and to the merchant and is precisely that kind of paper most valuable to the Institution, by showing how essential are the labours of Civil Engineers, to the welfare and progress of all countries. The Council would here point to the good example set by Sir John Rennie, who, amidst all his engagements, has never failed to devote his time and talents for the benefit of the Institution.

The descriptions of executed works by Mr. Hawkshaw, Mr. Bruce, Mr. Swinburne, and Mr. Hughes, were full of information on the methods of construction employed, and the precautions adopted, in cases where the magnitude of the works, the inroads of the sea, and the failure of a newly-invented system, demanded the prompt exercise of those energetic measures, which are the distinguishing characteristic of the English Engineer, and by which the word impossibility has been almost erased from his vocabulary.

In consequence of Mr. Hawkshaw being a Member of the

Council, no other notice can be taken, beyond honourable mention of the utility of his communication, and of the interesting discussion to which it gave rise.

Captain Laws, in his sketch of the mode of working the Oldham Incline, merely proved how much information it was in his power to communicate, on the great question of the working of Railways, which the Council trust will be fully brought before the Institution, during the present Session.

The essays by Mr. S. Clegg, jun., and Commander Heath, were both practically useful and in accordance with the views of our first President, in the establishment of the subjects for premiums; and the experiment of Mr. Homersham Cox "On the demonstration of the Rotation of the Earth," formed an interesting episode at one of the Meetings.

Mr. Leslie's system of gauging streams, and Mr. Blackwell's experiments "On the Discharge of Water by Overfalls, or Weirs," were both eminently useful; and it is anxiously desired, that records of similar observations should be transmitted to the Institution, even although they might not be in a fit state for laying before the Meetings, as they would be valuable for reference and would instruct other observers, in the mode by which similar experiments might be made.

The sketch by Mr. Glynn, of the recorded labours of the French Engineers, in their examination of the Isthmus of Suez, had the effect of drawing from Mr. Robert Stephenson, M. P., V. P., an interesting statement, of his observations of that ancient site of engineering operations, and of the intended works in the formation of the railway from Cairo, of which he will, it is hoped, ultimately give a fuller description; at the same time, he confirmed the account of the works executed for the Barrage of the Nile, under a French Engineer, Mougél Bey, in which a diving-bell of gigantic dimensions was employed; of this work, a description will be prepared, when Mougél Bey shall have transmitted a further account of his recent labours.

Mr. Newton's treatise, on "Patent Law Protection," although, perhaps, not strictly such as the Institution would desire to see frequently before it, embraced many topics of interest, to inventors, mechanics, and manufacturers, and induced an animated and useful discussion.

Some of these papers are now ready to be issued, in the first part of Vol. X. of the Minutes of Proceedings for 1850-51, with the second part of Vol. IX. for 1849-50. The concluding portions of the volumes still incomplete, will be issued, as soon as the

Finance Committee have it in their power to give instructions to proceed.

In the Council Report of last year, a Catalogue of the Library was promised; this engagement has been fulfilled, and it is gratifying to find, that not only is the utility of the work admitted by the Members, but the plan of its formation, and the accuracy of its execution, have been generally approved, by the best authorities. This catalogue is formed on a simple alphabetical system, giving under the author's name, an entire transcript of the title-page of each work, or tract, the subject entries being made as brief as possible, and the cross references being so multiplied, that scarcely any subject can escape unnoticed. The number of volumes in the Library is rather above three thousand, including fifteen hundred tracts, bound in assorted sets. The time required for the arrangement of the large number of slips for these volumes, and for the minute correction of the proofs, was greater than could be devoted to it by the Secretary, the Council, therefore, authorized his procuring assistance for the completion of the work, on the understanding that it should be executed under his superintendence. Accordingly Mr. James Forrest was engaged to examine and collate the original slips; and to extend the cross references, including all the books and pamphlets in the Library, up to the end of December 1850. To the conjoint labours of Mr. Manby (the Secretary) and Mr. Forrest, the Institution owes the possession of a comprehensive printed catalogue, and in future, a manuscript catalogue, with the same sub-entries, will be kept up, for the use of the Library, and will be printed at intervals.

One anticipated effect has already resulted from the circulation of the catalogue. Several of the Honorary Members and Members of the other classes, not finding in the list the works they had written, immediately transmitted them to the Library, whilst others, remembering the engagement they entered into, on election, purchased works, of which they were enabled to perceive the want, and contributed their quota for the general good.

The Council would impress upon the Members, how materially they may contribute to the value of the Library, by depositing there the Reports, and other documents, they frequently throw aside, as of only temporary value, the duplicates from their Libraries, or such other books as are likely to prove useful for reference.

The list of presents exhibits an improved appearance. From the Lords Commissioners of the Admiralty, and the Honourable Board of Ordnance, their valuable Charts have been transmitted, as usual, through the constant care of your Honorary Members, Admiral

Sir F. Beaufort and Major-General Colby; all the other Government departments have shown equally good intentions, and rarely refuse any request for what they publish. The interchanges of transactions with other Societies have continued, and are productive of mutual benefit, and particular attention should be directed to the gifts of Major-General Sir C. W. Pasley, the Rev. H. Moseley, Captain Simmons, R. E., Herr Förster, and Messrs. Airy, Mark Jones, Kennard, and Leach.

The amount of arrears of subscription for 1851, due November 30th, is—

From Members of all classes residing abroad.	£ 79	5	6
From Members of all classes residing in England	302	6	6
			£381 12 0

The total amount of arrears of the previous years, exclusive of 1851, is—

From Members of all classes residing abroad	£357	7	6
From Members of all classes residing in England	482	8	0
			839 15 6

Total	£1,221	7	6
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The amount of subscriptions collected, has been good, but the arrears continue so large, that in spite of their disinclination to have recourse to unpleasant measures, the Council feel it imperative, to take steps for erasing from the books, an illusory balance which there is little chance of ever seeing realized. Instructions have therefore been given, to enforce the provisions of Clause 10, Section V. :—

“Any person whose subscription is two years in arrear, that is to say, whose arrears and current subscriptions shall not have been paid on, or before the 1st of March, shall be reported to the Council, who shall direct application to be made for it; and in the event of its continuing one month in arrear, after such application, the Council shall have the power, after suitable remonstrance, by letter, in the form so provided, of erasing the name of the defaulter from the Register of the Institution.”

At the same time, it is their intention to have due regard to the provisions of Clause 11, Section V. :—

“In case any Member who has been long distinguished in his professional career, but who, from ill-health, advanced age, or other sufficient causes, does not continue to carry on a lucrative practice, the Council, if they find good reason for the remission of the annual subscription; may so remit it. Also they may remit any arrears which are due from an individual; or may accept a collection of books, or drawings, or models, or such other contribution as in their opinion, under the circumstances of the case, may entitle the person to be enrolled as a Life Subscriber, or to enable him to resume his former rank in the Institution which may have been in abeyance from any particular causes. These cases must be considered and reported upon by the Sub-Committee named for that purpose.”

It is hoped, that this expression of the necessity, for enforcing the provisions of the law, will suffice to determine the settlement of all the claims, as the indisposition of the Council to use extreme measures, must be well known and should be appreciated.

The number of Members and Associates elected is greater than during any Session since 1846, and the effective increase is steadily progressing.

The tabular statement of the transfers, elections, deceases, and resignations of Members of all classes, during the years 1849-50 and 1850-51, appears thus :—

	Honorary Members.	Members.	Associates.	Graduates.	Annual Increase.
1849-50					
Transferred to Members . .	..	..	1	..	} 38-31=7 31
Elections	..	7	31	..	
Deceases	1	8	6	..	
Resignations	..	1	12	3	
1850-51					
Transferred to Members . .	..	..	2	1	} 56-22=34 22
Elections	1	3	52	..	
Deceases	1	5	6	..	
Resignations	..	1	9	1	
Members of all Classes on the Books, November 30, 1851 . }	33	247	406	30	=716

If the Honorary Members and Graduates are omitted from the

calculation, the annual increase of Members and Associates stands thus :—

Years.	Members.	Associates.	Members Elected.	Deceases, Resignations, and Erasures.	Effective Increase.
1846	7	23	30	10	20
1847	8	21	29	19	10
1848	11	27	38	22	16
1849	18	31	49	11	38
1850	7	31	38	27	11
1851	3	52	55	20	35

The following Member, Associates, and Graduates having tendered their resignations, and their several subscriptions having been arranged, they have been permitted to retire from the Institution, in accordance with Clause 9, Section V., of the Bye Laws.

Charles Bourns, Member; John Boorer, *Æneas Coffey*, Thomas Fairbairn, Lieut.-Col. John Hambly Humfrey, Thomas Illman, George Briant Wheeler Jackson, Robert Charles May, George Moore, and Col. Sir William Reid, R.E., Associates; and James Routh, Graduate.

The deceases are the Most Noble the Marquis of Northampton, Honorary Member; William Brunton, Grant Samuel Dalrymple, John Farey, William Mackenzie, and Henry Renton, Members; Col. George Ritso Jervis, B.E.; James Hunter Tasker, George Benjamin Thorneycroft, William West, and John Wilson, Associates.

— SPENCER JOSHUA ALWYNE COMPTON, Marquis and Earl of Northampton, Earl Compton, of Compton in Warwickshire, and Baron Wilmington, of Wilmington, county of Sussex, was born on the 2nd of January 1790. At an early age he entered at Trinity College, Cambridge, and exhibited an attention to his collegiate duties, and studious habits, so unusual at that period among gentlemen commoners, that he gained the respect of the heads of houses, and acquired the esteem and regard of many eminent contemporaries, with whom he continued through life to cultivate the most friendly relations; among these may be mentioned Dr. Peacock, the present excellent Dean of Ely, Professor Sedgwick, the Archbishop of York, Sir John Herschel, Professor Ericsson, Dr. Whewell, Master of Trinity; Professor Airy, the Astronomer Royal; Bishop Thirlwall, and Professor Willis; all of whom were eventually to be seen around him, at those scientific meetings, over which he presided with such amenity, and at his soirées, which had such a beneficial effect, in promoting more intimate connexion between the

members of the aristocracy, and those classes whom they had not, hitherto, had any opportunity of knowing, or appreciating.

Soon after leaving the University, Lord Compton was elected to represent in Parliament, the borough of Northampton, and although the Hon. Spencer Perceval, the Premier, was his near relative, and all his connexions were Tories, he dared to think for himself, and unswayed by influence, maintained an independence of expression and liberal sentiments, which won for him the esteem of all parties. He became the earnest coadjutor of Wilberforce, in his strenuous efforts for abolishing the slave trade; and the same amiable feelings induced him to co-operate with Sir James Mackintosh, as a criminal law reformer, to take an active part in the discussion of the Alien Act, and the Seditious Meetings Act, and more recently to interfere actively, and successfully, on behalf of the Italian patriots, Santa Rosa, Gonfalonieri, Silvio Pellico and others, whose sufferings he deeply felt.

In 1815 he married Miss M'Cleane Clephane, a lady of rare talents, and highly cultivated taste and accomplishments, with which she combined those domestic virtues which eminently fitted her to be partner of so kind, courteous, and good a man as Lord Compton. For many years, Italy was the favourite residence of this excellent English family, and their countrymen, towards whom the most unbounded hospitality was practised, felt national pride in such worthy representatives of the British aristocracy.

In 1828 he succeeded to the title of Marquis of Northampton; and in 1830 on losing the excellent lady, who had for fifteen years been the pride and ornament of his home, he returned to England, determined to devote the remainder of his life to the education of his family, and the cultivation of science and art.

In that year he joined the Royal Society, and on the resignation of his Royal Highness the Duke of Sussex, in 1838, the Marquis of Northampton was, on account of his varied accomplishments and his love of science, selected as the fittest successor to the Presidential Chair. All who have had the privilege of attending the meetings of the Society, must have admired his constant attention to the duties of President, the good-humour, fairness and suavity with which he conducted the business, and the influence he exercised over the host of distinguished men who surrounded him; whilst at the soirées he gave, in his capacity of President, the best representatives of the rank, wealth, science, and art, in the country, were brought into intimate contact, and the influence of these réunions was of the happiest nature. He was a sound practical geologist, and communicated several papers to the Geological Society; he

was an excellent draughtsman, and having studied carefully the best examples of ancient art, he laboured assiduously to forward the architectural views, of Whewell, Willis and Peacock, and was induced to take an active part in archæological pursuits; eventually he became the President of the Archæological Institute, in whose favour he used his influence, to obtain permission for the meetings of the infant Society being held at the house of the Institution of Civil Engineers.

He laboured most assiduously on behalf of the British Association for the Advancement of Science, and on every emergency his active co-operation could be confidently relied on. His association with all the most eminent philosophers, his knowledge of their fellow-labourers on the Continent, his familiarity with foreign languages, and his cheerful and unbounded hospitality, rendered his period of Presidency eminently beneficial to the Royal Society, and his retirement from the Chair, in 1849, might have had prejudicial effects, but for the excellent selection of that distinguished astronomer and enlightened nobleman, the Earl of Rosse, to fill the vacant post.

The Marquis's acquaintance with literature was varied and extensive; he was a graceful and pleasing poet, his prose writings were manly and dignified, and his general literary merits were recognized, by his election, as President of the Royal Society of Literature.

He was elected an Honorary Member of this Institution in 1842; he was a frequent attendant at the Meetings, and on every occasion sought to meet the Civil Engineers, and to afford them every attention and facility for joining his own distinguished Society.

His health, at all times delicate, had been for some time more than ordinarily precarious, when he undertook a tour in the East, with his son-in-law, Viscount Alford, who was recommended to spend the winter in a milder climate. The change did not, however, act propitiously on either; Lord Alford died soon after his return to England, and the Marquis of Northampton, only survived him a few days: he expired on the 17th January 1851 in his 61st year, surrounded by the beloved family, to whose welfare he had unremittingly devoted himself;—lamented by all, to whom his unvarying kindness had endeared him, and admired as a brilliant example of a true British nobleman.

Mr. WILLIAM BRUNTON was born in May 1777, at Lochwinnoch, Ayrshire, Scotland. His father was a watch and clock maker, a trade which then engrossed all the minor mechanical works of the district, and in his shop, whilst yet a child, he laid the foundation of his subsequent mechanical proficiency, and under his grandfather, who was a colliery viewer, extensively employed, young William

Brunton became familiar with, and interested in, all the engineering operations of the neighbourhood. After the usual course of a plain education, he was, in the year 1790, put to work in the fitting shops of the New Lanark Mills, then recently erected by Mr. David Dale, in conjunction with Sir Richard Arkwright, from whose mills, in Derbyshire, everything in the new establishment was minutely copied, and a new race of cotton machine-makers was reared up. There young Brunton received the instructions of millwrights, carpenters, smiths, and other workmen, who had returned from the Cromford Mills, where they had been sent for a course of practical instruction. At New Lanark he remained, usefully employed, for about five years, when being attracted by the fame of the great works at Soho, he migrated to the South, and had the good fortune to be engaged as a workman, by Messrs. Boulton and Watt, in the year 1796, when they had obtained an extension of their patent, and had just secured a verdict for infringement, against some mine adventurers in Cornwall. Here he enlarged his scope of information, by diligent study, aided by the great advantage of association with such talented fellow-workmen, as Sotherton, Murdoch, Creighton and others: he gained also the confidence of his employers, and at the early age of twenty-one was sent alone, to the collieries of Mr. Curwen, in Westmoreland, to endeavour to rectify the defects of a pumping engine, which had been erected by the Soho firm. Of the difficulties which he had to encounter in this, his first campaign, he used to speak with great interest, to the latest period of his life. He remained at Soho until he was made foreman and superintendent of the engine manufactory, and being thus brought into close intercourse with Mr. Watt, towards the close of his life, he very frequently attended on him, in his last illness, being summoned to his couch, or to the side of an easy chair, in which the invalid was wheeled, to be within sight of interesting operations which were in progress. To Mr. Watt's unrepining sufferings, to his unimpaired intellect, and to his peaceful and kindly disposition, at that period, Mr. Brunton was accustomed frequently to recur; and in his own last painful illness (which in some degree resembled that of Mr. Watt) his friends perceived, that he exhibited the same qualities, which he had so often described, as the characteristics of his honoured friend and master.

In the year 1808, Mr. Brunton left Soho, and joined the Butterley works, then principally the property of the elder Mr. Jessop, and under his management; he there erected fitting shops, and established the manufacture of engines: he also represented the firm in many important missions, and thus made the acquaintance, and

became the friend of Mr. Rennie, Mr. Telford, and other eminent men of the day, with whom he had business relations. In 1815 Mr. Brunton left Butterley, and became a partner in and the mechanical manager of the Eagle Foundry, Birmingham, where he remained for ten years, during which time he designed and executed a great variety of important works. In 1825 his connexion with the Eagle Foundry ceased, and he removed to London, where he practised as a Civil Engineer, and obtained a share of the employment, which was, however, at that period not very widely diffused.

In 1835 he quitted the metropolis, and became a partner in the Cwm Avon tin works, where he erected the present copper smelting furnaces and rolling mills. In 1838 he left that establishment, and became connected with the Maesteg works and a brewery at Neath; here a total failure ensued, and the savings of his life were gone. From that period, Mr. Brunton, who had become a widower, resided with one, or other of his children, sometimes in Cornwall, sometimes in Monmouthshire, occupying his mind in various ways, and recently in an effort to improve the ventilation of collieries, of which invention he sent a model to the Exhibition, in Hyde Park. Up to June 1850 he occasionally reappeared in his profession, as his services were required by old friends and employers, but after his losses in Wales he never fully embarked in business.

As a mechanical engineer his works were various and important; many of them were in the adaptation of original and ingenious modes of reducing and manufacturing metals, and the improvement of the machinery connected therewith, such as those at Butterley, Dowlais, (where he was largely employed by Sir John Guest,) Cwm Avon, Swansea, and elsewhere. In the introduction of steam for navigation he had a large share; he made some of the first engines, used on the Humber and Trent, and was amongst the first on the Mersey, having made the engines for the vessel which first plied on the Liverpool ferries, in 1814. He fitted out the "Sir Francis Drake," at Plymouth in 1824, which is still afloat, and was the first steamer that ever took an English man-of-war in tow. In the course of his career, he obtained many patents, but derived little remuneration from them, although some are now in general use.

There is at this time scarcely a tin mine in Cornwall without his calciner, which is also in use for the treatment of silver ore, in Mexico; his fan regulator is a very valuable invention, but has been unproductive to him. At Butterley, he first applied the principle of a rapid rotation of the mould, in casting iron pipes, and after incurring great part of the expense of a patent, he found that a foreigner had previously secured one for the same process, in [1851-52.]

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casting terra cotta, and had recited in his specification, that the same mode might be applied to metals. Mr. Brunton's long experience enabled him to refer to many mechanical failures, including some of his own abortive schemes, to which he alluded freely and described humorously, but there was one, which, as it occasioned a sad loss of life, he never mentioned but with painful solemnity; it was his walking machine, called the steam horse, which he made at Butterley in 1813, and which worked, with a load, up a gradient of 1 in 36, during all the winter of 1814, at the Newbottle Colliery, but which eventually exploded and killed thirteen persons. In writing to a friend in 1850 Mr. Brunton thus alludes to it:—

“The act of propulsion resembled a man pushing a weight forward; the thighs were suspended to links at the top, and by radius bars like a parallel motion, the knee joint moved in the line, and was attached to the piston rod direct. The leg was connected to a joint of the thigh a little below the knee, and of such a length as when the foot rested on the ground, it formed an angle of propulsion varying from 20° to 30° from the perpendicular. The lower end of the leg was furnished with an universal, or coffin joint to the shoe, which resembled two horse-shoes joined at the open end, and two or three triangular cross-bars to prevent slipping.

“In operation the legs moved alternately, and the length of the step being 6 feet, each propulsion moved the machine 12 feet onwards. The facility with which it could be regulated in slipping upon, or over anything was very perfect. I was permitted to enlarge the new boiler, because the restriction to 5 tons weight was found an unnecessary precaution, for the tendency of the engine in operation was to raise the engine off the rails, and I found it needful to connect the first waggon to the engine by a chain at such an angle, as to lay the weight of the waggon partly upon the engine.”

In his active mechanical career of sixty years, Mr. Brunton had become known to all the leading men of the period, beginning with Sir Richard Arkwright, and continuing down to the present period. The names of Watt, Rennie, Jessop, and Telford have already been mentioned, as also those of his distinguished fellow-workmen at Soho; to these may be added the names of Wolfe, Trevithick, the elder Simpson, Sir M. I. Brunel, Seaward, George Stephenson, and others now no more. Of the good old school which they constituted, Mr. Brunton was, it is to be feared, almost the last. There are living a few of the older members of the profession, who knew him in his active life; many remember him in his declining years, and all will unite in doing justice to the excellent qualities of his head and heart.

He died in peace and comfort on the 5th of October, 1851, at the house of his son William, at Cambourne, in Cornwall, in his seventy-fourth year, sustained to the last by those religious principles, in the profession and practice of which he had consistently lived, through the course of a long and active career.

Mr. GRANT SAMUEL DALRYMPLE, the son of Lieut.-Colonel Kirkby Dalrymple, of Murran, East Lothian, was born in India, in the year 1816. His education was completed at the College of St. Andrews, whence he entered the Dundee Foundry, to learn the practical part of the profession, for which he was destined. He then served a period of pupillage under the Messrs. Stevenson at Edinbro', and by them was employed on several coast surveys, for Lighthouse purposes. During this period he attended assiduously the Classes of Dr. D. B. Reid, and laid the foundation of the taste for those studies, which he eventually pursued with such avidity. He then visited France, for the purpose of examining the Civil Engineering works of that country, and on his return drew up a Report, with sketches, of the state of the Cherbourg Breakwater.

He then entered the offices of Messrs. Walker and Burges, under whom he was engaged in the works for Hunstanton Lighthouse, and on the construction of the Cofferdam and River Terrace Wall of the New Houses of Parliament, a description of which he gave to the Institution in the Session of 1840.*

In the year 1842 he received an appointment from the Admiralty, and was engaged at Malta and Gibraltar, under Mr. W. Scamp (M. Inst. C. E.), in the construction of marine and other works, for the Government, until 1847, when, in consequence of a severe attack of fever, he returned to London, where, after the partial recovery of his health, he practised as a Civil Engineer, and was engaged in surveys in the Fens of Essex and Lincolnshire, prosecuting, at the same time, his chemical studies with great assiduity, up to the period of his unfortunate decease, which occurred suddenly, on the 17th of April 1851, in his thirty-fifth year.

Mr. Dalrymple joined the Institution, as a Member, in 1848, was very constant in his attendance at the Meetings, and was always ready to contribute, in every way, to the welfare of the Institution, to which he made numerous presents of useful books, even up to within a day preceding his death. He was a fine high-spirited young man, who endeared himself, by his kind and frank disposition, to all with whom he was connected, and had he been spared, would probably have attained a good position in the profession.

* Vide Minutes of Proceedings Inst. C.E. vol. i., (1840), p. 18.

Mr. JOHN FAREY was born in Lambeth, on the 20th March 1791, and was brought up and educated at Woburn, near the seat of Francis Duke of Bedford, to whom his father was agent. The interest taken by the Duke, in Agriculture, and which eventually, with the efforts of the Board of Agriculture, contributed to the formation of the Royal Agricultural Society of England, induced Mr. Farey, sen., to devote much of his time to the subject, and he wrote several articles in the early numbers of the "Agricultural Magazine;" he was regarded as an authority in geological questions, and being much employed in making reports in that capacity, was enabled to collect the materials for his survey of Derbyshire,* which enjoyed, at that time, considerable reputation.

The literary engagements of the father naturally influenced the tastes of the children, and from the early age of fourteen, and many years subsequently, Mr. John Farey was, with his brother and sisters, engaged in making the drawings for the illustrative plates of Rees' and the "Edinburgh Encyclopædias," "Tilloch's Magazine," "Gregory's Mechanics," and "Mechanical Dictionary," the "Pantologia," and many other scientific works, several of which he either edited, or contributed articles to.

The patient industry and habits of laborious research, which were the leading features of his character, aided by a remarkably retentive memory, peculiarly fitted him for the duties of this position, and to him, in conjunction with Messrs. Lowries, the engravers, may, with justice, be ascribed, in a great degree, the merit of introducing a better style of illustration in our scientific works. Here also he laid the foundation for one portion of his subsequent professional career, and in after years, when consulted on patent cases, the accuracy of his information, as to the principle and forms of machines, the minute details of processes, the names of inventors, and the dates of introduction, showed that the impressions of early life were indelibly fixed, and this mental store very rarely proved inadequate to the demands upon it.

The necessity of accomplishing a large number of drawings, with great accuracy, frequently within a limited time, naturally excited the inventive faculties, and the result was, the introduction, in 1807, of an instrument for making perspective drawings, a description of which was published in the "Transactions of the Society of Arts,"† and was rewarded by the Silver Medal; and in 1813 he invented the

* General View of the Agriculture and Minerals of Derbyshire, &c., by John Farey, sen., 2 vols. 8vo. London, 1811.

† Vide Trans. Soc. Arts, London, vol. xxxii., p. 71.

machine for drawing ellipses, to which he subsequently made many additions, and for which the Gold Medal of the Society of Arts was awarded; he also introduced many improvements in the drawing instruments and scales, now generally in use.

He was introduced, at a very early age, to the most eminent engineers and scientific men of the period, among whom were Watt, Telford, Rennie, Jessop, *Mylne, Bramah, Donkin, Brunel, Maudslay, Huddart, Bentham, Ramsden, Troughton, Davy, Wollaston, and Sir Joseph Banks, by whom, acting in conjunction with Messrs. Huddart, Jessop, Mylne, and Rennie, he was employed to prepare for publication, Smeaton's Reports and Drawings, the originals of which were accordingly intrusted to him for that purpose.*

In 1819 he went to St. Petersburg, and other parts of Russia, where he was engaged as a Civil Engineer in the construction of iron-works. There he first saw a steam-engine indicator, then attempted to be kept a profound secret: his inquiring disposition soon discovered the qualities of the instrument, with which he made many experiments; on his return to England, he employed M'Naught to construct them for general use, and thenceforth he was continually employed to use the instrument, in disputed cases of the power of steam-engines.

In 1821 he relinquished all his professional engagements in favour of his brother Joseph, and embarked in a lace manufactory, in Devonshire, which, however, he gave up in 1823, and in 1825 took the engineering direction of Messrs. Marshall's flax mills, at Leeds; this position he was obliged to relinquish in 1826, in consequence of the failure of his brother's health, and the necessity for his return to London, where he resumed his profession of consulting Civil Engineer, and from that time was engaged in most of the novel inventions, important trials in litigated patent cases, and scientific investigations, during the last quarter of a century. For this branch of the profession, Mr. Farey was peculiarly qualified, by natural tastes, by early pursuits and subsequent engagements; and during a long and active career, it may be asserted, that however his opinions, or his decisions, may have been questioned by the losing party, the fearless honesty of his evidence was never once impugned, by either side. His laborious research into authority for cases, was proverbial, and his habits of order and regularity rendered his office and library models for these qualities. In this, as in the preparation of the drawings for specifications, he received invaluable assistance from Mrs. Farey, a lady of rare attainments, who to great amiability of

* Vide Preface to Smeaton's Reports, page x.

disposition, and a thorough knowledge of the duties of her sex, joined almost masculine scientific attainments, which she employed as modestly, as profitably, in aiding the labours of her husband, who never fully recovered the shock occasioned by her decease.

Mr. Farey's principal scientific work was a *Treatise on the Steam Engine*,* giving in the first volume, which is all that has been published, a complete historical and practical account of the invention; from its first recorded origin, up to the period when Watt, Sotherton, and their cotemporaries, resigned into other hands the management of the works at Soho, where had been nursed and raised to maturity that giant power, which has done so much for the welfare of nations, and to which it does not appear possible, at present, to assign any limit. The work abounds with useful information, and rules for calculation and construction, and it is to be regretted that constant engagements, and, latterly, failing health, prevented the completion of the other volumes.

Mr. Farey joined the Institution, as a Member, in 1826; served several offices in the Council, took a very active part in the arrangement of the bye-laws, made several communications to, and participated in most of the discussions at, the meetings, and was ever ready to devote any amount of time, or money, to the advancement of the welfare of the Institution, by the members of which he was universally esteemed, and in their minds he will ever be regarded as a good and upright man.

His health received a severe shock, at the time of the burning of his residence in Great Guildford Street, when considerable portions of his library and documents were injured, or destroyed, and he died on the 17th July, 1851, in his sixtieth year, beloved and regretted by all who knew him.

Mr. WILLIAM MACKENZIE was born at Burnley, Lancashire, on the 20th March, 1794, at which period his father was engaged in the construction of the Leeds and Liverpool Canal. Young William Mackenzie was early apprenticed to a weaver, but the occupation was so distasteful to him, that he burned his warp, and ran away.

In the year 1811 he was bound apprentice to Mr. Thomas Clapham, lock carpenter of the Leeds and Liverpool Canal; he was soon transferred to the works of the Harbour, at Troon, Ayrshire, then constructing under the direction of Mr. John Clapham, the resident engineer, who was also the agent for the Duke of Portland; here commenced his acquaintance with the construction of cranes, waggons, caissons, and the general plant for engineering operations,

* "*Treatise on the Steam Engine, Historical, Practical, and Descriptive*," by John Farey. 4to. Plates. London, 1827. (The first volume only.)

as well as the modes adopted in submarine building, as the foundations of the works were laid in a depth of 2 fathoms below low-water mark.

On the sudden decease of Mr. Clapham, which occurred from the accidental discharge of a fowling-piece, he was released from his indentures, and in a short time was employed by Mr. Cargill, the contractor, at the Craigellicpie Iron Bridge, then erecting under Mr. Telford.

He then returned to England, and was engaged on various canal and other works, until about 1816-17, when he was employed by Mr. M'Intosh, as agent in measuring, levelling, setting out, and taking account of the work on the Union Canal, between Falkirk and Edinburgh, then constructing under Mr. Hugh Baird. From thence he was transferred to the Gloucester and Berkeley Canal, where he remained until its completion, and then in 1824 quitted the employment of Mr. M'Intosh, for an appointment by Mr. Telford, to superintend the construction of the Mythe Bridge, across the Severn, near Tewkesbury. He was then engaged until 1832, in fulfilling the duties of resident engineer, under Mr. Telford, on the Birmingham Canal, where the works, executed by him, are still considered the finest of the kind in Great Britain.

At this period the railway system began to assume an important position, and although it required a struggle to overcome his prejudice against the new order of things, Mr. Mackenzie, at last determining to swim with the stream, became the contractor for the Passenger Tunnel, from Edge Hill to the Lime Street station, of the Liverpool and Manchester Railway, under Mr. Stephenson. Other contracts, on the Grand Junction, and the Glasgow, Paisley, and Greenock lines, under Mr. Locke, M.P., on the North Union and the Midland lines, under Mr. Vignoles, and on the Manchester and Salford Junction Canal, followed in rapid succession.

In 1840, he undertook several extensive contracts for the hydraulic works of the Shannon Navigation, under Mr. Rhodes. The large weir, &c., at Killaloe, the weir and lock at Mellick, the bridge and approaches at Banagher and at Shannon Bridge, the lock and weir at Roorky, with the dredging operations and deepening the shallows, were all works of importance, and attended with difficulties in their execution, which demanded all his skill and energy to surmount; yet so perfectly did he meet the wishes of the Shannon Commissioners, that on completing the contracts, they voluntarily testified, that he was the only contractor from whom they had parted, without litigation of any kind.

In 1840 commenced the connexion with Mr. Brassey, in con-

junction with whom, the greatest amount of railway works in France, and elsewhere, ever previously undertaken by one firm, was successfully executed. The following enumeration will give some idea of the extent of the contracts.

The greater portion of the Paris and Rouen line, and the whole of the Rouen and Havre, including the stations and the maintenance of way of both lines, as well as the line from Rouen to Dieppe, all under Mr. Locke, and Mr. Newmann. Part of the Amiens and Boulogne line. The Canal works at Bar le Duc; and the Orleans, Tours, and Bordeaux contract, which latter is still in course of execution.

The revolution of 1848 put a stop to many contemplated undertakings, and the political state of France, up to the present time, has to a certain extent, arrested the progress of all peaceful enterprises, and railway progress on the Continent generally.

In that year, however, the short railway, 18 miles in length, between Barcelona and Matara, was completed under Mr. Locke.

In the mean time Messrs. Mackenzie and Brassey had not been idle in England; the Eastern Union line, under Mr. Locke and Mr. Bruff, was taken and completed; and in conjunction with the late Mr. John Stephenson, the whole of the lines from Lancaster, to Edinburgh and Glasgow, under Mr. Locke and Mr. Errington, with their numerous tributary branches and extensions, the Scottish Central to Perth, and the Scottish Midland to Forfar, with extraordinary rapidity. Part of the Chester and Holyhead line, under Mr. R. Stephenson, M.P. (V.P.); part of the North Staffordshire, under Mr. Bidder; the whole of the Trent Valley, under Mr. Stephenson; the Ormskirk branch of the East Lancashire Railway, under Mr. Locke and Mr. Errington; and the works of Greenock Harbour, under Mr. Locke, must be added to the list, which to the uninitiated, must appear of almost fabulous extent, when the absolute expenditure on these works is considered. In round numbers, the amount of the contracts taken, and of work executed, by Mr. Mackenzie alone, and in conjunction with Mr. Brassey and Mr. John Stephenson, may be estimated at upwards of seventeen millions sterling.

It was not, however, so much by the amount of the work undertaken, as by the manner of executing it, that Messrs. Mackenzie and Brassey astonished our Gallic neighbours; and when on the fall of the great viaduct at Barenton, instead of entering into litigation, or contesting their liability, they stepped forward without a murmur, and commenced the construction as a matter of ordinary duty, the most sceptical were obliged to admit the good faith and integrity of the English contractors.

Nothing but the most untiring energy and perseverance, allied with great physical power, and moral courage, could have supported any man through such mental and bodily labour: but with a quick and ardent temperament, he combined a kind and benevolent disposition, which aided him to overcome difficulties that would have worn out other men.

The fatigue he underwent, proved at last too much for his frame; in 1848 he suffered from an attack of gangrene in his foot, induced by exposure to the cold. In the following year, whilst on his way to Italy, he was again attacked by the same disease, which carried away his foot up to the ankle joint; he, however, apparently recovered, but still suffered severely at times, and on the 19th of October, 1851, in his 58th year, he expired, generally esteemed by all with whom he had come in contact, in his extensive affairs, and affectionately regretted by his family and friends, for as a son, a brother, and a friend he had few equals.

Mr. Mackenzie's industry and exertions were crowned with success, and he has left an ample fortune. On the day he died, his name was placed on the commission of the peace, for the county of Dumfries, where he had purchased an estate.

In the course of his works in France, he was admitted to the confidence and esteem of H. M. Louis Philippe, with whom he had frequent and lengthened interviews; and at one time it was asserted, that he exercised considerable influence over that Monarch's opinions; Mr. Mackenzie, however, always asserted that the topics of his communications were only the difficulties encountered in the execution of the public works, and the advantages to be expected by their ultimate extension.

At the opening of the Tours and Poitiers section of the Orleans, Tours and Bordeaux Railway, the Prince President of the French Republic, after complimenting Mr. Mackenzie on the rapid execution of the work, announced the intention of conferring on him the Cross of the Legion of Honour, at the same time expressing a hope, that the English Government would permit him to accept and wear it.

Mr. Mackenzie joined the Institution as a corresponding Member in 1828, and was transferred to the class of Members in 1837. His occupations prevented his frequent attendance at the meetings, but he always evinced anxiety for the welfare of the society, and was ready to concur in any measure for its benefit.

At his decease the English Press and the French Journals united in praise of him as a man, and in regret for the premature decease of one of the men of the new era.

— Mr. HENRY RENTON was born in June, 1815, at Apperly Bridge,

near Leeds, and after receiving a liberal education at Rawdon Academy, he became, at the age of fifteen, a pupil of his uncle, Mr. Thomas Rhodes (M. Inst. C. E.), at that time resident engineer for the construction of the St. Katherine Docks, London. In that position he had the good fortune to attract the notice of Mr. Telford, who being struck with his mathematical attainments, his proficiency as a draughtsman and surveyor, and his general abilities, took him into his office, where he remained for some time. He was then employed as assistant to Mr. Rhodes on surveys, and in preparing plans for the improvement of the Rivers Shannon, Ouse, and Severn, the Harbours of Hartlepool, Berwick, and Limerick, as well as for several other works. In 1839, he was appointed the principal assistant of Mr. Rhodes, on the works of the Shannon navigation, and on the completion of the plans and reports, he became resident engineer on some of the most important contracts, among which may be mentioned the Bridge at Banagher, Mellich Lock and Weir, the Canal, Locks, and Bridge at James Town, and many others.

He was then engaged on railway surveys, in England; and in 1846, became the resident engineer under Mr. Grainger (M. Inst. C. E.) on the Leeds and Dewsbury Railway, where the mode of execution of the Brent Tunnel at Morley, and the other works, gave great satisfaction.

He then practised in London as a Civil Engineer for a short time, but his health failing, he removed to his native place, where he expired, after a protracted illness, on the 16th June 1851; respected for his talents and integrity, and beloved for his warm-hearted kindness and amiable disposition.

Mr. Renton joined the Institution as an Associate, in 1837, was transferred to the class of Graduates in the same year, and to the class of Members in 1847; and contributed a paper and drawings descriptive of a self-acting wasteboard at Naburn Lock, on the river Ouse*, for which he received a Telford Medal.

Colonel GEORGE RITSO JERVIS was born at Madras, on the 8th of October, 1794. His father, who held the post of Lieutenant-Governor of Ceylon, was the elder brother of the Chief Justice of Chester, and the uncle of the present Lord Chief Justice of the Common Pleas. His decease alone precluded his succession to the title of Earl St. Vincent, which was eventually conferred by special grant of the Crown, on Mr. Edward Ricketts, the descendant of the sister of Lady St. Vincent.

The subject of this memoir was the eldest of four brothers, the

* Vide Min. of Proc. Inst. C.E., vol. i. (1840), p. 26.

two elder of whom entered into the service of the Honourable East India Company, in the Engineer corps, and the two younger in the Artillery; and seeing much active service, all were enabled to attain rank, whilst gaining the approbation of the government, and the highest testimonials from their immediate commanders.

At the age of sixteen, George Jervis was sent to the Military Academy at Marlow, whence he was removed to the Royal Military Academy at Woolwich, and completed his studies at the then recently founded East India Company's College at Addiscombe, where his early attainments attracted the attention and commendation of his superiors, and secured his nomination to the Engineer corps.

On his arrival in India, in 1810, he was detached on service with a division of the army under General Walker, at that time besieging the forts of Chya and Nowanugger; where, on one occasion, by his dexterity in the management of a gun, under his charge, he dismantled and silenced a particular gun in one of the enemy's batteries, which had occasioned serious casualties among the artillerymen, and the troops generally. This instance of skill and coolness, secured him through after life the distinguished favour of Colonel Sir Lionel Smith, and established his reputation as a rising officer.

On the termination of the campaign, he was employed in the construction of civil engineering works, such as roads, bridges, &c., in the province of Baroda, until 1819, when he was recalled to active field service, on the staff of General Sir William Keir Grant, then commanding one of the divisions of the army under the Marquis of Hastings. His chivalrous gallantry in several actions soon distinguished him from his comrades, and won the public thanks of the Commander-in-Chief, whilst it secured the esteem and respect of the veterans amongst whom he served.

It is not, however, for his military services, brilliant and valuable as they were, that he will be remembered. It is as the active co-adjutor of that enlightened statesman, the illustrious Mountstuart Elphinstone, in his benevolent and wise endeavours to spread the blessing of education among the native Indians, that the name of Colonel Jervis will descend to posterity. Many circumstances combined to render his co-operation most valuable, and in fact almost indispensable, for this great undertaking. He was as great a proficient in all the theoretical branches of education, as in the practical duties of the several special services, and he was a good oriental scholar. Being at the head of the Engineering department of the Bombay Presidency, he was enabled to employ, beneficially, all the native talent that was developed, and above all, his indomitable energy

and unwearied zeal, enabled him to overcome obstacles which would have paralyzed other men.

The duties of the Engineer officers in India, are, of necessity, more comprehensive than those of the Royal Engineers in this country; indeed, when not engaged in active military service, they perform all the duties of Civil Engineers, designing and superintending the execution of Public Works of every kind, such as the construction of Roads, Bridges, Tanks and Hydraulic Works, whether for the irrigation, or drainage of the country, or the improvement of the Rivers, Docks, Harbours, Lighthouses, and Machinery of all kinds; in addition to which they must possess such a knowledge of Architecture, as will enable them to design and erect all the principal public buildings; and Surveying in all its branches, from the trigonometrical lines of a province, to the simple measurement of a field, must be familiar to them. The performance of these onerous duties was rendered more difficult by the want of efficient assistants; and the forming of these, first induced the attention of Colonel Jervis to the subject of native education in India. After many partially successful attempts, he founded, in about the year 1823, the "Engineers' Institution," the design of which was "to prepare an efficient body of young men, to act under Officers on Engineering Works;" and for the diffusion of scientific knowledge among them. To this establishment he devoted much time, and for the pupils, he commenced the translation into the Marathi and Guzerathi dialects, of some of the most useful educational and scientific works of the period, which he afterwards extended, among others, to Hutton's Mathematics, De Morgan's Works, and several of Lord Brougham's writings. He also introduced the process of lithographic printing, till then unknown in India. The natives, thus educated, were found so useful, and general attention was so directed to the subject, that when, on the retirement of the Honourable Mountstuart Elphinstone from the Government in 1827, it became a question how the general feeling of respect and affection of all classes of Europeans and Natives could be most appropriately demonstrated, the princes and chieftains, the wealthy merchants of Western India, and a large body of the most intelligent and influential Hindoos, Parsees, and Mahomedans, acting under the advice of their tried friend Colonel Jervis, determined to found a College and Schools for the free and public instruction of all classes, and to name it after the distinguished scholar, statesman, and soldier, who had ever shown such affectionate solicitude for their welfare. Thus was established the Elphinstone College at Bombay, for which the sum of £16,500 was subscribed in one day, by those who were desirous of showing their

affection for their Governor, whilst they aided in the benefits he had striven to confer on them. Subsequent contributions from the Directors of the H. E. I. Company, and from private individuals, have enabled professorships to be founded, and the instruction imparted to the natives has proved most valuable. In 1843 it was determined to establish a class of Civil Engineering, and your Associate, Mr. William Pole, was appointed the Professor, on the recommendation of the Council of this Institution. On his arrival at the College, in 1844, he received all kindness and attention from Colonel Jervis, who, although differing from the Government in some of the details of the plan, warmly lent his aid, and gave every facility afforded by his department of the service; and on the return of Mr. Pole to England in 1847, on account of ill health, all the pupils of the class were received into active employment, on the works of the Engineering Department of the Presidency.

Colonel Jervis held the chief command of the Engineer corps for nine years, during which time he originated and caused the execution of many important and useful public works; among which may be mentioned, giving a better supply of water to the Town and Island of Bombay, improving the drainage, perfecting the defences of that important station, completing the Harbour, the Docks, and the Warehouses; the construction of a dam for the supply of water for the city of Poonah, and extending the defences of Aden. These are only a few of the objects to which his active mind was directed, and amidst his official occupations he found time to fulfil the duties of General Superintendent of Public Education,—Examiner of Oriental languages for the Civil Service, and Syndic, or Examiner of the Translation of the Scriptures, then in progress under that excellent prelate Bishop Heber, with whom he actively co-operated in all his educational plans.

Colonel Jervis joined the Institution, as an Associate, in the year 1841, and made frequent use of it, during his short residence in England, and by correspondence on his return to India.

The bodily labour induced by his unwearied energy, proved too much for his health, which became seriously impaired, and he retired for quiet and repose to Boulogne-sur-Mer, France, where on the 14th October, 1851, at the age of fifty-seven, he closed an unremittingly active career of forty-one years, in the service of his country, enjoying the respect of the Government, the attachment of his brother officers, and the affection of his friends.

Mr. JAMES HUNTER TASKER was born at Greenock, in the year 1822, and in due course prosecuted his studies at the College, at Glasgow, where he distinguished himself by his general acquire-

ments, but more particularly by his attainments in mathematics, and carried off some honours.

In 1840-41 he became the pupil of Mr. J. E. Errington (M. Inst. C. E.), under whom he was engaged on most of the lines of Scottish Railways, and eventually was appointed the Resident Engineer, during the construction of the Scottish Central Line, the works of which, as of the Scottish Midland Line, he brought to a satisfactory termination. He continued, until 1850, in the management of the former of these lines, when a change having occurred in the direction, he accepted the post of general Manager of the Aberdeen Railway, but had scarcely commenced his duties, when he was seized with fever, which, after a very few days' illness terminated, on the 9th of January 1851, at the early age of twenty-nine years, a life which promised to be valuable to his fellow-creatures.

Mr. Tasker was elected an Associate of this Institution in 1844. He possessed considerable attainments in the theory as well as the practice of his profession, and his conciliating disposition and business habits, rendered his assistance in the conduct of Bills before Committees of the House, very valuable to his friends and agreeable to his antagonists. His early decease was much regretted by Messrs. Locke and Errington, under whom he had been so long engaged, and by a large circle of friends.

— Mr. GEORGE BENJAMIN THORNEYCROFT was born at Tipton (Staffordshire), on the 20th August 1791, whence he removed with his parents, at a very early age, to Kirkstall Forge, near Leeds, where he was employed until his eighteenth year. On his return into Staffordshire, in about 1809, he worked at the Moorcroft Iron Works, near Bilston, and in consequence of his general good character and his skill as a workman, he was appointed to a confidential position, as a superintendent, which post he occupied until about the year 1817. He then founded a small iron-work at Wilkenhall, and in the year 1824, in conjunction with his brother, the late Mr. Edward Thorneycroft, established the Shrubbery Iron Works, near Wolverhampton. These works were commenced on a very small scale, producing only about 10 tons of iron per week, but the skill and knowledge possessed by the master, and the admirable selection of the workmen, from among the best hands in the country, soon gained a high character for the iron produced, and an extensive demand springing up, the 'make' was gradually increased to nearly 800 tons per week. The railway system offered to his ready perception a great field, of which he was not slow in availing himself, and his practical ability was exercised in the selection of materials, and in the improvement of the modes of

manipulation, by which the produce of the Shrubbery Iron Works eventually acquired so high a reputation.

He became an eminent ironmaster, and amassed considerable wealth, which he employed liberally and with great judgment, for the benefit of the town of Wolverhampton, of which he was elected the first Mayor, on the Charter of Incorporation being obtained; but it was among his workmen that his good qualities were most apparent, and with such an example before them, of the position that might be attained by talent, industry, and probity, it is not to be wondered at that he was their 'model master.' Sturdy and inflexible against brute force, but ductile and yielding under the influence of reason and common sense, he was a type of the trade he represented, as of that energetic Saxon race of which we can still boast so many fine specimens.

To the poor he was a bountiful benefactor, readily relieving their temporary wants, and liberally founding and supporting permanent charities for their benefit.

As a Magistrate he was firm and upright in his judgments, which were dictated by plain common sense, and he very frequently was so successful a mediator between litigants, as to preclude the necessity for recourse to legal proceedings.

It was however in his social circle that the real character of Mr. Thorneycroft could be best appreciated; and one of his family in writing of him says—"Scenes and circumstances, comparatively trifling to others, would strike the tenderest chords of his large heart, and call forth expressions of feeling not common in their nature. One of his greatest delights was to recount to us, the struggles and incidents of his early days, and I know not which was most happy, he in telling, or ourselves in listening, to those often repeated, but still fresh and welcome traditions of his past history. In the family circle he displayed a degree of instinctive courtesy, which casual observers might not have associated with his character, and his conversation was always peculiarly weighty in its import and refined in its tone."

A few years ago Mr. Thorneycroft was seriously injured by the explosion of a boiler at his works at Willenhall, and from the effects of this accident he never perfectly recovered. In the early part of this year disease of the brain occurred, which apparently yielded to judicious treatment, but a relapse took place, and on the 28th of April 1851, he terminated a useful career, in his 60th year, lamented by rich and poor. His remains were attended to their last home, by a numerous body of his brother ironmasters, and by upwards of a thousand of his workmen, many of whom, commencing their career under him, had grown grey in his service, and "among

the thousand men who followed their popular master to the grave, there was not one, perhaps, who began the world with less than he did, or who in following strictly his good example, might not have ended their career as honourably."

Mr. Thorneycroft only joined the Institution as an Associate in the year 1850, and yet, amidst his numerous occupations, he complied with the engagement entered into on his election, by communicating a very interesting paper "On the manufacture of Malleable Iron and the Strength of Railway Axles," to which a Telford Medal was awarded, and the clear forcible manner in which he expounded his views, on a subject so familiar to him, will long be recollected with pleasure.

— Mr. WILLIAM WEST, a member of the Society of Friends, was born in the year 1792 at Wandsworth, Surrey, and after the usual course of practice he settled at Leeds, in 1816, as a chemist. His natural taste induced him to devote much time to the study of analytical chemistry and science generally, and in 1831 he was appointed Lecturer on chemistry to the Leeds School of Medicine, a post which he filled for fourteen years with great credit. He was an active promoter of the Philosophical and Literary Society, and eventually became its President elect, as well as the President of the West Riding Geological and Polytechnic Society. He was connected with the London Chemical Society; assisted in the formation, and was a constant attendant at the meetings, of the British Association for the Advancement of Science, frequently contributing papers, and and in 1846 he was elected a Fellow of the Royal Society. In 1842 he became an Associate of the Institution of Civil Engineers, and contributed several useful papers, which are published in the Transactions and Minutes of Proceedings, and for one of them a Telford Medal was awarded in the session of 1846.*

During the latter part of his career, particularly after his retirement from business, he took an active part in the proceedings of the Societies with which he was connected, and being extensively employed in scientific investigations for legal cases, for which his patient habits of research and strict integrity, peculiarly fitted him, he was enabled to make many interesting communications to the meetings of these Societies. His philanthropic exertions were constantly engaged on a variety of objects, and at his decease, on the 10th September 1851, at the age of fifty-nine years, a well-merited eulogium on him appeared in the journals of the town of his adoption.

* Mr. West's decease alone prevented that notice by the Premium Committee, which his last paper "On Explosions in Coal-Mines" would otherwise have received.—*Sec. Inst. C.E.*

Mr. JOHN WILSON was a native of the parish of Govan, near Glasgow, being born in the year 1787, at his father's farm of Broomhill, where after receiving an ordinary plain education, he was engaged in agricultural pursuits, until his eighteenth year, when having exhibited considerable talent as a draughtsman, he was selected by the late Mr. Colin Dunlop, to fill a position of trust, as manager of a department of the Clyde Iron Works. Here he commenced a severe course of study, at the University of Glasgow, to qualify himself for the duties he might have to perform, and acquired that knowledge of the theory of chemistry, mineralogy, geology, and Civil Engineering, which, being subsequently perfected by practice, was eminently useful in his own works, and induced his being frequently consulted by others on important undertakings.

Within a few years after his connexion with the Clyde Iron Works, his services were found so valuable, that he was admitted to a partnership in the concern, the chief management of which eventually devolved upon him, on the demise of Mr. Colin Dunlop.

About the year 1824 the experiments which led to the use of the 'hot-blast' in iron furnaces were commenced by Mr. J. B. Neilson (M. Inst. C. E.), of the Glasgow Gas Works. During their progress, Mr. Wilson evinced great interest in them, contributed materially to their success, by his advice, and eventually, having practically proved the value of the discovery, introduced it into the Clyde Works, and became a partner in the patent, which was granted in 1829. The success and economy attending this invention, the revolution it produced in the manufacture of iron, the litigation with the infringers of the patent, by which upwards of one hundred thousand pounds were recovered, on the issue of one case, and the vast revenue resulting from the Royalty of one shilling per ton of iron, manufactured under licence, are too well known, to be dwelt on here. It should, however, be stated, that although, as possessing only one-tenth of the patent, it would have been manifestly to his interest, as an extensive iron-maker, to have abrogated the patent, yet, with great disinterestedness, he stood foremost in the battle for the patentees, and it was chiefly by his energy and through his means, that this protracted litigation was brought to a successful issue.

About the year 1831-32 he commenced the erection of the Dundyvan furnaces, and rolling-mills, in connexion with a large mineral tract, rented from Mr. Hozier, of Newlands, and Mr. Buchanan, of Drumpeller. Here the famous black-band iron ore and excellent fuel, with the use of hot-blast, combined to produce pig iron of great fusibility, in such quantities and at a price hitherto considered impossible, in Staffordshire and in Wales. Only four blast-furnaces were originally built, but on the retirement of

[1851-52.]

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Messrs. Dunlop from the concern, which occurred in 1835-6, Mr. Wilson commenced the extension of the works, which now have nine furnaces, and a large rolling-mill, in which a capital of about £300,000 has been invested, and where upwards of four hundred workmen are employed.

In the year 1838, Mr. Wilson became the purchaser of the estate of Arden, near Airdrie, consisting of about 700 acres, whence he extracted the minerals for use at his various works, reserving a portion of the surface for the establishment of a large dairy farm. Here he built a village for the habitation of the workmen, with a school so endowed as to afford their children education at a very small expense, and by the general system adopted and the judicious improvements he executed, the actual value of the estate, for which he originally paid £18,000 must now be doubled.

He then took a lease of the estate of Kinneil, where he erected four blast-furnaces, to consume the minerals on the spot, and at a very considerable cost, designed and executed the railway, with numerous inclined planes, by which the produce is brought to the shipping port. Part of this estate was subsequently purchased by him, and he at times occupied the Dean House and old Kinneil mansion, at one time the residence of the celebrated Dugald Stewart.

In conjunction with Messrs. Dunlop, in 1845-6, Mr. Wilson leased from Sir James Boswell, of Auchinleck, the minerals under the Lugar Estate, and erected there four blast-furnaces, which, with the opening of the mines, occasioned an outlay of full £150,000. Of these works he subsequently became the sole proprietor, and recently he purchased the Muirkirk Works, in Ayrshire, comprising two furnaces and a rolling-mill, at which were manufactured the rails which were the subject of the lawsuit with the Glasgow and South Western Railway Company, under which Mr. Wilson recently obtained £22,500 damages and £2,500 costs.

Recently he purchased from Sir James Colquhoun, Bart. of Luss, the mansion and estate of Ardenconnel, where he principally resided and where his decease occurred suddenly, from disease of the heart, on the 9th November 1851, in his sixty-first year.

The distinguished position in the manufacturing world, attained by Mr. Wilson, gave him considerable influence in Glasgow and its vicinity, and he employed it with great judgment and uprightness for the general good.

He was ever foremost in the promotion of public improvements, took great interest in municipal affairs, being a member of the Town Council, and devoted much attention to the works on the Clyde and the extension of the harbour at Glasgow. His opinion and advice were constantly in request, and his judgment as an arbitrator was

always received with deference, on account of his acknowledged honesty of purpose. From peculiar circumstances he never obtained a seat in Parliament, but had his life been spared, there was every probability of his being returned at the next election, to have swelled the ranks of those energetic men who by their own good sense, talents, and industry have arrived within the portals of St. Stephens, which only a few years since, rarely opened to the 'men of the people.'

Mr. Wilson joined the Institution, as an Associate, in 1844: whenever he visited the metropolis he rarely failed to be present at the meetings, and the announcement of the title of Member, or Associate, by any gentleman visiting the Dundyan Works sufficed to insure for him the utmost attention and hospitality.

The notice of the rapid progress of Mr. Wilson, and of his ultimate acquisition of vast wealth, has been dwelt on chiefly for the purpose of exhibiting to those who are in similar positions, what may be accomplished by steady industry; for here we see without the development of any wonderful, or peculiar faculty, the farmer's son, attaining perhaps the most enviable position,—that of a British manufacturer and merchant, contributing largely to the prosperity of his country, giving employment to and conferring happiness upon a great number of his fellow-creatures, distributing his wealth liberally, free from the trammels entailed by titles, enjoying and feeling proud of his position, and at his death beloved by all who were admitted to his intimacy, and universally regretted publicly as an upright honest man.

In the balloting list Mr. James Meadows Rendel, the senior Vice-President, is, in conformity with the bye-laws, proposed as the successor of Sir William Cubitt, who vacates the Presidential Chair, after occupying it for two years. Mr. Joseph Locke, M. P., is proposed for filling the vacancy among the Vice-Presidents, and the names of Mr. Peter William Barlow, Captain William Scarth Moorsom, and Mr. John Scott Russell, Members; Messrs. George Appold, Edward Ladd Betts, Thomas Russell Crampton, and George Hennem, Associates, are submitted for the other vacancies.

In retiring to the ranks, whence your votes elevated them, the Council would express a fervent hope that their efforts may have proved satisfactory to you, and that their successors may reap a plentiful harvest from the seed sown during the past session; there is a vast field open to our noble profession, and it is only necessary to be united heart and hand, and to follow the great example of some of those, now taken from among us, to confirm universal confidence in the skill, honour and integrity of English Engineers.

RECEIPTS.										
<i>Dr.</i>					£.	s.	d.	£.	s.	d.
To Balance in the hands of the Treasurer								222	8	7
— Subscriptions and Fees:—										
Arrears					107	12	6			
Current					1,418	11	0			
Fees					166	19	0			
Life					49	7	0			
								1,742	9	6
— Council Premiums								45	0	0
— Publications:—Sale of Minutes of Proceedings								94	16	0
— Telford Fund:—Dividends, one year								56	13	6

£2,161 7 7

PAYMENTS.

<i>Cr.</i>	£.	s.	d.	£.	s.	d.
By House, Great George Street, for Alterations	.	.	.	2	4	5
Ditto, For Rent	364	1	2			
Rates and Taxes	20	3	3			
Insurance	18	19	9			
				403	4	2
— Salaries				300	0	0
— Commission on Collection of Subscriptions				41	7	9
— Clerk, Messenger, and Housekeeper				121	12	0
— Postage and Parcels :—						
General	46	18	11			
Parcels	1	4	1			
				48	3	0
— Stationery, Engraving, and Printing Circulars, Cards, &c. .				70	17	7
— Coals, Candles, Oil and Gas :—						
Coals	29	11	0			
Candles	8	2	0			
Oil	7	4	7			
Gas	52	14	2			
				97	11	9
— Tea and Coffee				40	19	1
— Library :—						
Catalogue	55	16	8			
Books	13	13	0			
Periodicals	30	10	10			
				100	0	6
— Publication :—Minutes of Proceedings				683	10	5
— Furniture, Gas-fittings, Lamps, &c.				15	8	10
— Telford Premiums				24	17	4
— Council Premiums				13	4	10
— Diplomas for Members				7	8	11
— Manuscripts, Original Papers, and Drawings				5	15	0
— Incidental Expenses :—						
Sending Invitations and Cards, procuring						
Models, &c., for Conversazione	52	14	9			
Gratuities and Christmas Gifts	1	4	6			
Occasional Assistance	4	1	0			
Assistance at Meetings	6	5	0			
Beating Carpets and Sweeping Chimneys	4	12	0			
Household Utensils, Repairs and Expenses	33	6	11			
				102	4	2
				2,078	9	9
— Balance in the hands of the Treasurer				82	17	10
				£2,161	7	7

Examined and compared the above Account with the vouchers entered in the Cash Book, and found to be correct, leaving a balance in the hands of the Treasurer of Eighty-two Pounds, Seventeen Shillings and Ten Pence.— November 30th, 1851.

(Signed)

WILLIAM SWANN, }
GEORGE APPOLD, } *Auditors.*

CHARLES MANBY, *Secretary.*]

December 22, 1851.

PREMIUMS AWARDED,

SESSION 1850-51.

THE Council of the Institution of Civil Engineers have awarded the following Premiums:—

1. A Telford Medal, in Silver, to Samuel Clegg, jun., M. Inst. C. E., for his paper "On Foundations, Natural and Artificial."
2. A Telford Medal, in Silver, to Matthew Digby Wyatt, Assoc. Inst. C. E., for his paper "On the Construction of the Building for the Exhibition of the Works of Industry of All Nations in 1851."
3. A Telford Medal, in Silver, to Henry Swinburne, for his paper, "Account of the Sea Walls at Penmaen Mawr, on the line of the Chester and Holyhead Railway."
4. A Telford Medal, in Silver, to George Barclay Bruce, M. Inst. C. E., for his paper, "Description of the Bridge built over the River Tweed, on the line of the York, Newcastle and Berwick Railway."
5. A Telford Medal, in Silver, to John Hughes, Assoc. Inst. C. E., for his paper "On the Pneumatic method adopted in constructing the Foundations of the new Bridge across the Medway, at Rochester."
6. A Telford Medal, in Silver, to William Price Struvé, M. Inst. C. E., for his paper "On the Ventilation of Collieries, theoretically and practically considered."
7. A Telford Medal, in Silver, to Alfred Vincent Newton, for his paper "An inquiry into the nature of Patent Law Protection, with a view to the better appreciation and security of the Inventor's rights."
8. A Council Premium of Books, suitably bound and inscribed, to Joseph Glynn, M. Inst. C. E., for his paper "On the Isthmus of Suez, and the Canals of Egypt."
9. A Council Premium of Books, suitably bound and inscribed, to Thomas Evans Blackwell, M. Inst. C. E., for his paper, "Results of a series of Practical Experiments on the Discharge of Water by Overfalls."
10. A Council Premium of Books, suitably bound and inscribed, to James Leslie, M. Inst. C. E., for his paper, "Proposal

for a mode of Computation, whereby Floodwater may be excluded from a set of Gaugings."

11. A Council Premium of Books, suitably bound and inscribed, to Henry Carr, Assoc. Inst. C. E., for the Drawings illustrating his paper, "Description of two Bridges over the River Don and Canal, &c., at Spotbro', near Doncaster."

SUBJECTS FOR PREMIUMS,

SESSION 1851-52.

THE Council invite communications on the following, as well as other subjects, for Premiums :—

1. A general investigation of the laws of the Flux and Reflux of the Tide in Estuaries.
2. On the principles upon which the works for the improvement of River Navigation should be conducted, and the effects of the works upon the Drainage and Irrigation of the district.
3. The improvement and maintenance of natural, or artificial Harbours; the most efficient means of clearing away deposits by the use of Backwater, or by directing the natural currents.
4. The selection of Sites for, and the principles of the construction of, Breakwaters and of Harbours of Refuge; illustrated by Examples of existing works.
5. The forms and construction of Piers, Moles, or Breakwaters (whether Solid or on Arches), Sea-walls, and Shore Defences; illustrated by Examples of known constructions, such as the Cobb Wall at Lyme Regis, &c.
6. The best System of forming Artificial Foundations, showing the ratio of pressure to surface, and the soil best calculated to sustain heavy structures; illustrated by the best Examples in modern practice, and by accounts of the failures of large works.
7. On Brick and Tile-making, and the capability of introducing new forms for Engineering and Architectural purposes. With the processes most useful to Emigrants and Settlers.
8. On the application of Wrought Iron, on a large scale, to Engineering and Architectural Structures.
9. Accounts of Experiments on the Strength of Metal Trusses and Columns used in Buildings.
10. Improvements in the construction of Girder Bridges, whether

- of Trussed Timber, of Cast Iron, trussed, or plain, or of hollow Wrought Iron beams.
11. The construction of Suspension Bridges, with Rigid Platforms, and the modes of Anchoring the Stay Chains.
 12. The comparative advantages of Iron and Wood, or of both materials combined, for the construction of Steam Vessels, with drawings and descriptions ;—the methods for preventing corrosion ;—and details of the arrangements for the Com-passes in Iron Ships.
 13. On the changes that have been introduced, within the last fifteen years, in the Lines of Ships and Steam Vessels ; and an examination of the effects produced by the new Law of Measurement for Tonnage.
 14. The best method of External Condensation, so as to permit the employment of salt, or of hard water, and furnishing pure water for the Boiler. With a description of various systems of Evaporating, Refrigerating, &c.
 15. The results of the use of Tubular Boilers, and of Steam at an increased pressure, for Marine and other Engines ; and of the most successful means for avoiding Smoke in Furnaces of all descriptions.
 16. The application of the principle of Expansion to the improvement of Steam Engines for producing rotary motion.
 17. On the application of Steam Power to Canal Navigation.
 18. The Economy of Railways as a means of transit, comprising the classification of the traffic, in relation to the most appropriate speeds for the conveyance of passengers and merchandise.
 19. The arrangement and distribution of the Workshops at the principal repairing station of a Railway, for the repairs and maintenance of the Locomotives, Passenger, and other carriages, &c.
 20. The construction of Locomotive Engines, specially adapted for steep inclines ; with accounts of Experiments, demonstrating the comparative value of large and small Engines, under various circumstances.
 21. Improvements in the construction of Railway Carriages and Waggons, with a view to the reduction of the gross weight of passenger trains. Also of Railway Wheels, Axles, Bearings, and Breaks ; treating particularly their ascertained duration and their relative friction.
 22. The construction and duration, of the Permanent Way of Railways in Europe, and the modifications most suitable for India, Egypt, &c.

23. Railway Accidents; their cause and means of prevention; detailing particularly the various contrivances which are in use, and have been proposed; with the regulations of some of the principal lines.
24. The Electric Telegraph; the several improvements in its construction, particularly as regards the insulation of the wires, and the various uses to which it has been applied.
25. The results of Experiments for obtaining motive power through the agency of Galvanism.
26. The results of Experiments made with various Dynamometers for the purpose of ascertaining the different ratios between power and effect in machinery generally.
27. The conveyance and distribution of Water in Towns; the sources from whence it may be derived; a description of the different modes of collecting and filtering; and an account of the advantages, or disadvantages of the high service constant supply system.
28. The Drainage and Sewerage of large Towns; exemplified by accounts of the system at present pursued, with regard to the level and position of the outfall, the form and dimensions of the sewers, the prevention of emanations from them, the disposal of the sewage, and of the arrangements for connecting the house drains with the public sewers.
29. On Warming and Ventilating buildings.
30. Improvements in the system of Lighting by Gas; the results of the use of Clay Retorts,—of large Ovens (for producing a better quality of Coke,)—of Exhausters, Condensers, and modes of Purifying, and the precautions for the economical distribution of Gas.
31. A Mathematical, or Geometrical Demonstration of the advantages of Flat Sails for Ships, over those of different degrees of curvature, when exposed to direct, or slanting winds.
32. On the Application of Machinery, combined with Mechanical Power, and the means of transporting manure and produce, on large Farms and Agricultural Establishments; and on improvements in the plan of the works and buildings, and the 'plant' employed.
33. The most effective arrangement and form of Centrifugal and Reciprocating Blowing Apparatus.
34. Description of Cast, or Wrought Iron Cranes, Scaffolding and Machinery, employed in large works, in Stone Quarries, &c., especially where steam is used as a motive power.
35. On the Improvements which may be effected in the Buildings,

Machinery, and Apparatus for producing Sugar from the Cane, in the Plantations and Sugar Works of the British Colonies, and the comparison with Beet-root, with regard to quantity, quality, and economy of manufacture.

36. Description of the Machinery adapted for the preparation of Indian Cotton.
37. Improvements in Flax Machinery, and in the processes for preparing the Flax for manipulation.
38. Notice of the principal Self-acting Tools employed in the manufacture of Engines and Machines; also of Moulding Machines and Wood-working Machines; and the effect of their introduction.
39. On the best system of remedying the inconvenience resulting from the present Want of Uniformity between the Weights, Measures, and Coins of the different countries of Europe.
40. Memoirs and accounts of the Works and Inventions of any of the following Engineers:—Sir Hugh Middleton, Arthur Woolf, Jonathan Hornblower, Richard Trevithick, William Murdoch (of Soho), and Alexander Nimmo.

Original Papers, Reports, or Designs, of these, or other eminent individuals, are particularly valuable for the Library of the Institution.

The communications must be forwarded, on or before the 30th of March, 1852, to the house of the Institution, No. 25, Great George Street, Westminster, where copies of this paper, and any further information may be obtained.

CHARLES MANBY, *Secretary*.

25, *Great George Street, Westminster,*
November 1st, 1851.

Notice.

It has frequently occurred, that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers, or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

Extracts from the Minutes of Council, February 23rd, 1835.

“ The principal subjects for which Premiums will be given, are—

- “ 1st. Descriptions, accompanied by Plans and explanatory Drawings, of any work in Civil Engineering, as far as absolutely executed; and which shall contain authentic details of the progress of the Work. (Smeaton's Account of the Edystone Lighthouse may be taken as an example.)
 - “ 2ndly. Models, or Drawings, with descriptions of useful Engines and Machines; Plans of Harbours, Bridges, Roads, Rivers, Canals, Mines, &c.; Surveys and Sections of Districts of Country.
 - “ 3rdly. Practical Essays on subjects connected with Civil Engineering, such as Geology, Mineralogy, Chemistry, Physics, Mechanic Arts, Statistics, Agriculture, &c.; together with Models, Drawings, or Descriptions of any new and useful Apparatus, or Instruments, applicable to the purposes of Engineering or Surveying.”
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Instructions for preparing Communications.

The communications should be written in the impersonal pronoun, and be legibly transcribed on foolscap paper, about thirteen inches, by eight inches, the lines being three-quarters of an inch apart, on the one side only leaving a margin of one inch and a-half in width on the left side, in order that the sheets may be bound.

The Drawings should be on mounted paper, and with as many details as may be necessary to illustrate the subject, and should be to such a scale that they may be clearly visible, when suspended on the walls of the Theatre of the Institution, at the time of reading the communication, or enlarged Diagrams may be sent for the illustration of any particular portions.

Papers which have been read at the Meetings of other Scientific Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

Excerpt Bye Laws, Section XIV., Clause 3.

“ Every Paper, Map, Plan, Drawing, or Model presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse, or delay the publication of such paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary, of his intention. No person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council.”

ORIGINAL COMMUNICATIONS,

DRAWINGS, PRESENTS, &c.,

RECEIVED BETWEEN JUNE 30, 1850, AND JUNE 29, 1851.

ORIGINAL COMMUNICATIONS.

AUTHORS.

- Blackwell, T. E. No. 853. Results of a Series of Practical Experiments on the discharge of Water by Overfalls. With five diagrams, and sketches appended to the paper.
- Bruce, G. B. No. 835. Description of the Bridge built over the River Tweed, on the line of the York, Newcastle, and Berwick Railway. With thirteen drawings, Nos. 4532 to 4544.
- Cameron, J. No. 856. A Description of Ballochmyle Viaduct, on the line of the Glasgow and South Western Railway. With two drawings, Nos. 4545-6.
- Carr, H. No. 848. Description of two Bridges over the river Don and Canal, with the Lodge and approaches, on the estate of Sir Joseph Copley, Bart., at Sprotbro', near Doncaster. Accompanied by the specification and detailed estimate. With twelve drawings. Nos. 4547 to 4558.
- Clegg, S. jun. No. 850. On Foundations, Natural and Artificial. With sixteen diagrams.
- Cox, H. No. 852. On the demonstration of the rotation of the earth, by means of two pendulums.
- Doyne, W. T. No. 851. An investigation of the Strains upon the diagonals of lattice beams, with the resulting formulæ. With diagrams.
- Glynn, J. No. 859. On the Isthmus of Suez, and the Canals of Egypt. With large outline map.
- Gunn, J. C. No. 845. Description of a Timber Bridge over the River Dee, at Braemar. With one drawing, No. 4559.
- Hawkshaw, J. No. 849. Description of the Lockwood Viaduct on the Huddersfield and Sheffield Railway. With three drawings. Nos. 4514 to 4516.

AUTHORS.

- Hughes, J. No. 858. On the Pneumatic Method adopted in constructing the Foundations of the New Bridge, across the Medway, at Rochester. With three drawings. Nos. 4560 to 4562.
- Lane, C. B. No. 855. Account of the works on the Birmingham Extension of the Birmingham and Oxford Junction Railway. With ten drawings, Nos. 4563 to 4572.
- Laws, Capt. J. M., R.N. No. 846. Description of the Mode of working an inclined plane of 1 in $27\frac{1}{4}$ on the Oldham Branch of the Lancashire and Yorkshire Railway. With one drawing, No. 4513.
- Leslie, J. No. 817. On a mode of computation for excluding Floodwater from a set of gaugings of a stream, taken at regular intervals.
- Macdonnell, I. J. No. 844. Description of a Turn Table, 42 feet in diameter, in use on the Bristol and Exeter Railway. With one drawing, No. 4573.
- May, C. No. 854. Account of a Swing Bridge over the river Rother, at Rye, on the line of the Ashford and Hastings Branch of the South Eastern Railway. With one drawing, No. 4574, and four diagrams.
- Moorsom, Captain W. S. No. 857. Description of the Viaduct over the River Nore, near Thomastown, in the county of Kilkenny, to carry the Waterford and Kilkenny Railway. With five diagrams.
- Newton, A. V. No. 847. An Inquiry into the nature of Patent Law protection, with a view to the better appreciation and security of the Inventor's rights.
- Struvé, W. P. No. 842. The ventilation of Collieries theoretically and practically considered. With seven diagrams.
- West, W. No. 841. A comparative View of the Recorded Explosions in Coal Mines. With two diagrams.
- Wyatt, M. D. No. 843. On the Construction of the Building for the Exhibition of the Works of Industry of all Nations in 1851. With thirty diagrams.
-

ORIGINAL DRAWINGS.

DONORS.

- Bruce, G. B.** Nos. 4532-44. Plans, elevations and details of works on the Tweed contract of the York, Newcastle and Berwick Railway, including the Royal Border Bridge over the river Tweed, at Berwick; with details of the cofferdams, the centering, and mode of carrying on the work, and of the temporary timber bridge. Paper No. 835.
- Cameron, J.** Nos. 4545-6. Elevations, plans, sections, and details of the Ballochmyle Viaduct, on the line of the Glasgow and South Western Railway. Paper No. 856.
- Carr, H.** Nos. 4547-58. Elevations, plans, sections, and details of two bridges over the river Don and Canal, on the estate of Sir Joseph Copley, Bart, at Sprotbro' near Doncaster; with elevations and details of the lodge and lodge gates. Paper No. 848.
- Gunn, J. C.** No. 4559. Elevations and Sections of the Bridge over the river Dee, at Braemar. Paper No. 845.
- Hawkshaw, J.** Nos. 4514-16. Plan, elevation, details, and view of the Lockwood Viaduct, on the Huddersfield and Manchester Railway. Paper No. 849.
- Hughes, J.** Nos. 4560-62. Elevations, plans, sections, and details of the Pneumatic Apparatus used in constructing the Foundations of the new Bridge across the Medway, at Rochester. Paper No. 858.
- Lane, C. B.** Nos. 4563-72. Isometrical elevations, and orthographic sections of details, of the works on the Birmingham Extension of the Birmingham and Oxford Junction Railway. Paper No. 855.
- Laws, Capt. J. M., R.N.** No. 4513. Plan and section of the Oldham Branch of the Lancashire and Yorkshire Railway. Paper No. 846.
- Macdonnell, I. J.** No. 4573. Plan and sections of a Turntable, 42 feet in diameter, in use on the Bristol and Exeter Railway. Paper No. 844.
- May, C.** No. 4574. Elevation and plan of a Swing Bridge over the river Rother at Rye, on the line of the Ashford and Hastings Branch of the South Eastern Railway. Paper No. 854.
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CATALOGUE OF PRESENTS.

BOOKS.

- | DONORS. | TITLE OF WORK. |
|---|---|
| Académie Royale des Sciences, des Lettres, et des Beaux-Arts de Belgique, Annuaire de l'Académie, Seizième année. 8vo. Bruxelles, 1850. | |
| _____ | Bulletins de l'Académie. Tome XVI., 2de Partie, et Tome XVII., 1re partie, 8vo. Bruxelles, 1849-50. |
| _____ | Catalogue des livres de la Bibliothèque de l'Académie, 8vo. Bruxelles, 1850. |
| _____ | Mémoires couronnés et Mémoires des savans étrangers publiés par l'Académie. Tome XXIII. 4to. Bruxelles, 1850. |
| _____ | Mémoires de l'Académie. Tomes XXIV. XXV. 4to. Bruxelles, 1850. |
| _____ | Exposé général de l'Agriculture Luxembourgeoise, ou dissertation raisonnée sur les meilleurs moyens de fertiliser les landes des Ardennes, sous le triple point de vue, de la création de forêts, d'enclos, de rideaux d'arbres, de prairies, et de terres arables, ainsi que sous le rapport de l'irrigation, par H. le Docte. 8vo. Bruxelles, 1849. |
| _____ | Mémoire sur la chimie et physiologie végétales et sur l'agriculture; en reponse à la question suivante, proposée par l'Académie royale de Belgique. "Exposer et discuter les travaux et les nouvelles vues des physiologistes et des chimistes sur les engrais et sur leur faculté, &c.," par H. le Docte. 8vo. Bruxelles, 1849. |
| _____ | Mémoire sur le paupérisme dans les Flandres, par E. Dupetiaux. 8vo. Bruxelles, 1850. |
| Airy, G. B. | Account of the Improvements in Chronometers, made by Mr. John Sweetman Eiffe, for which a reward was granted to him by the Lords Commissioners of the Admiralty; with an Appendix, containing Mr. Robert Molyneux's Specification of a Patent for Improvements in Chronometers. 4to. Plates. London, 1842. |

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Airy, G. B. Account of the Northumberland Equatorial and Dome, attached to the Cambridge Observatory. By G. B. Airy. 4to. Plates. Cambridge, 1844.

———— Appendices to the Greenwich Observations for 1848-9, including the Results of Magnetical and Meteorological Observations, Indications of Magnetometers. 4to. London, 1848-9.

[Extracted from the Greenwich Observations.]

———— Catalogue of 2156 Stars, formed from the observations made during twelve years, from 1836 to 1847, at the Royal Observatory, Greenwich. 4to. London, 1849.

———— Description of the Altitude and Azimuth Instrument, erected at the Royal Observatory, Greenwich, in the year 1847. By G. B. Airy. 4to. Plates. No place or date.

[Extracted from the Introduction to the Greenwich Astronomical Observations, 1847.]

———— Description of the Instruments and Process used in the Photographic Self-registration of the Magnetical and Meteorological Instruments, at the Royal Observatory, Greenwich. By G. B. Airy. 4to. Plates. London, 1849.

[Extracted from the Introduction to the Greenwich Magnetical and Meteorological Observations, 1847.]

———— Determination of the Longitude of Valentia, in Ireland, by the transmission of Chronometers. By G. B. Airy. 4to. Map. No place, 1846.

[Forming the Appendix to the Greenwich Astronomical Observations, 1845.]

———— Explanation of a proposed construction of Zenith Sector; addressed to the Board of Visitors of the Royal Observatory, Greenwich. By G. B. Airy. 4to. Plate. No place, 1848.

———— Magnetical and Meteorological Observations, made at the Royal Observatory, Greenwich, in the years 1843, 4, 5, 6, and 7. By G. B. Airy. 5 vols. 4to. Plates. London, 1845-49.

———— Plan of the Buildings and Grounds of the Royal Observatory, Greenwich, with Explanations and History. 4to. Plate. London, 1847.

[Extracted from the Introduction to the Greenwich Observations, 1845.]

[1851-52.]

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TITLE OF WORK.

Airy, G. B. Results of the Astronomical Observations made at the Royal Observatory, Greenwich, 1847, 8, and 9. 4to. London, 1847-49.

[Extracted from the Greenwich Observations.]

Alexander, W. Plan and description of the original Electro-magnetic Telegraph, with prefatory note to the Royal Commissioners of the Exhibition of the Works of Industry of All Nations, and relative documents. By W. Alexander. Tract, 8vo. Plate. Edinburgh, 1851.

Anonymous. National Benevolent Emigration Fund. Correspondence with Her Majesty's Government on Emigration. Tract, 8vo. London, 1850.

Plan for shortening the time of Passage between New York and London, with documents relating thereto, including the proceedings of the Railway Convention at Portland, Maine, and the Charter of the European and North American Railway, with the subsequent Acts and resolves passed by the legislature of Maine, and the doings of the Committee in relation thereto. Tract, 8vo. Map. Portland, U. S., 1850.

[Published by order of the Convocation.]

Atherton, C. On marine engine construction and classification. With an Appendix, describing the theoretical principle and practical construction of Atherton's patent eccentric expansion apparatus. By C. Atherton. 8vo. Plates. London, 1851.

Beardmore, N. Suggestions for a new Street, through the city of London, from Waterloo Bridge to the Commercial Road, with a leading Aqueduct Sewer, &c. &c. By N. Beardmore. Tract, 8vo. Map and Section. London, 1850.

Bethell, J. New Patent Improvements in preserving Timber, and also in drying and seasoning it. Tract, 8vo. London, 1850.

Bevan, W. Memoirs of the Geological Survey of Great Britain, and of the Museum of Economic Geology in London. Vols. 1 and 2, Parts 1 and 2. 8vo. Plates and cuts. London, 1846 and 8.

Board of Admiralty, (through Admiral Sir F. Beaufort, Hon. Mem. Inst. C. E.) A table for finding the latitude from the altitude of the Polar Star, observed at any hour in the

DONORS.

TITLE OF WORK.

- northern hemisphere. By W. Salmon. 8vo. London 1850.
- Board of Admiralty. Sailing Directions for the Lower Shannon, and for Lough Derg, with some hydrographic notices of Lough Ree and Lough Erne. By Commander J. Wolfe, R. N. 8vo. 2nd edition. London, 1850.
-
- Tide Tables for the English and Irish Ports for the year 1851. 8vo. London, 1850.
- Botfield, B. Journal of a Tour through the Highlands of Scotland during the summer of 1829. By B. Botfield. 8vo. Plates. Edinburgh, 1830.
- Browne, J. Balloon Railway across the Great Desert of Sahara, Africa. By J. Browne. Tract, 8vo. London, 1852.
- Burt, H. P. Illustrations of the remains of Roman Art in Cirencester, the seat of ancient Corinium. By Professor Buckman and C. H. Newmarch. 4to. Plates and Cuts. Cirencester, 1850.
- Cambridge Observatory. Astronomical Observations made at the Observatory of Cambridge. Vol. XVI., for the years 1844 and 1845. By the Rev. J. Challis, M. A. 4to. Cambridge, 1851.
- Cambridge Philosophical Society. Transactions. Vol. IX., Part I. 4to. Plates. Cambridge, 1851.
- Chemical Society of London, Quarterly Journal. Nos. XI. and XII. 8vo. 1850-51.
- Cini, T. Del modo di migliorare l'arte del ferro in Toscana. By T. Cini. 8vo. Firenze, 1849.
- Conrad, F. W. Catalogus van eene verzameling Kaarten berustende op de bibliotheek der Utrechtsche Hoogeschool. Bijlage bij de verhandeligen van het Koninklijk Instituut van Ingenieurs. 8vo. 1850.
-
- Verhandeligen van het Koninklijk Instituut van Ingenieurs. Derde stuk 1849; vierde stuk & vijfde stuk 1850. 8vo. Plates. 'S Gravenhage, 1849-50.
- Cox, H. A Manual of the Differential Calculus, with simple Examples. By H. Cox. 8vo. Cuts. Cambridge, 1851.
- Curry, H. Railway economy; a treatise on the new art of transport, its management, prospects, and relations, commercial, financial, and social; with an exposition of the

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- practical results of the Railways in operation in the United Kingdom, on the Continent, and in America. By Dr. D. Lardner. 8vo. London, 1850.
- Curry, H. Recent improvements in arts, manufactures, and mines, being the 2nd edition of a Supplement to the 3rd edition of the Dictionary. By Dr. A. Ure. 8vo. Cuts. London, 1846.
- Experimental researches in Electricity, by Dr. M. Faraday. 2 vols. 8vo. 2nd edition. Plates. London, 1849.
- [Reprinted from the Phil. Trans. for 1831-8.]
- Dalrymple, G. S. A dictionary of Chemistry and Mineralogy, with an account of the processes employed in many of the most important chemical manufactures. To which are added a description of chemical apparatus, and various useful tables of weights and measures, chemical instruments, &c.; and an Appendix. By A. and C. R. Aikin. 2 vols. 4to. Plates. London, 1807-14.
- The Life of the Honorable Henry Cavendish; including abstracts of his more important scientific papers, and a critical inquiry into the claims of all the alleged discoverers of the composition of water. By George Wilson, M. D. 8vo. Plate. London, 1851.
- [Printed for the Cavendish Society.]
- Traité de l'exploitation des Mines. Par Ch. Combes. 3 vols. 8vo. Folio and 4to. Atlas of Plates. Paris, 1844, 5, and 6.
- De la Beche, Sir H. Third Report on the Coals suited to the Steam Navy. By Sir H. de la Beche and Dr. L. Playfair. Folio. London, 1851.
- Denham, Capt., R. N. Parliamentary Paper; Return—Light-houses. Ordered to be printed, August, 1850.
- Donaldson, G. A Manual of Chemistry, by W. T. Brande. 2 vols. 8vo. Cuts. London, 1848.
- Doull, A. Canadian Land and Railway Association; Report and outline of a plan, by which an extensive Railway may be constructed in the British North American Colonies, combining its execution with an enlargement of colonization and reclamation of waste land, and executing the works, so that the Company and the emigrants shall be

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- mutually benefited. By A. Doull. Tract, 8vo. Map and plan. London, 1850.
- FÖRSTER, C. F. L.** (of Vienna). *Allgemeine Bauzeitung, für Architekten, Ingenieure, Dekorateurs, Bauprofessionisten, Oekonomen, Bauunternehmer, &c.* From 1837 to 1849. By C. F. L. Förster. 4to. Folio atlas of Plates for each year. Wien, 1837 to 1849. With two Appendices. I. *Literatur und Anzeigeblatt für das Baufach.* 3 vols. 4to. Wien, 1837 to 1849. II. *Ephemeriden für das Baufach.* 2 vols. 4to. Wien, 1844 to 1848.
- Franklin Institute ; Journal.** Vols. XVIII. and XIX. Third series. 8vo. Plates and Cuts. Philadelphia, 1850.
- Frome, Capt., R.E.** *Outline of the method of conducting a Trigonometrical Survey, for the formation of geographical and topographical maps and plans ; military reconnaissance, levelling, &c. ; with the most useful problems in geodesy and practical astronomy, with formulæ and tables for facilitating their calculation.* By Capt. Frome, R.E. 8vo. 2nd Edition. Cuts. London, 1850.
- Geological Society of Dublin ; Journal.** Vol. IV. Part II. No. 2. 8vo. Dublin. No date.
- Grantham, R. B.** *Plan of the Islington Cattle Market, with the proposed additions.* By R. B. Grantham. Tract, 4to. 2nd edition. Plan. London, 1850.
- Gwyn, H. M. P.** *Specimens of inlaid tiles, heraldic, and encaustic, from Neath Abbey, Glamorganshire, by the Rev. H. H. Knight and E. Moxham.* Folio. Plates. Edinburgh, no date.
- Harness, Capt., R.E.** *Report from the Select Committee on the Royal Mint, together with the Minutes of Evidence, Appendix, and Index.* Folio. London, 1847.
- *Report of the Commissioners appointed to inquire into the Constitution, Management, and Expense of the Royal Mint.* Folio. London, 1849.
- Harris, T.** *The advantages and capabilities of the port of Plymouth, as a packet station, with some suggestions for its improvement.* By T. Harris. Tract, 8vo. Plates and Cuts. Plymouth, 1851.
- Hawkshaw, J.** *Report on the Rolling Stock and Permanent Way, and the question of a reserve, or equalizing fund.* Ad-

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| Homersham, S. C. | Review of the report on the supply of water to the Metropolis ; containing a report to the Directors of the London (Watford) Spring Water Company. By S. C. Homersham. Tract, 8vo. London, 1850. |
| Hübbe, H. | Verhandlungen du Elbe—Stromschan—Commission der betreffenden Uferstaaten über die Schiffbarkeit der Elbe und deren Verbesserung. Folio. Hamburg, 1850. |
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A Treatise on Analytical Geometry of three dimensions, containing the theory of curve surfaces, and of curves of double curvature. By J. Hymers, D.D. 8vo. Plates. Third edition. Cambridge, 1848.

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A Treatise on Plane and Spherical Trigonometry, and on trigonometrical tables and Logarithms, together with a selection of problems, and their solutions. By J. Hymers, D.D. 8vo. 3rd edition. Plates. Cambridge, 1847.

A Treatise on Statistics, containing the theory of the equilibrium of forces, and numerous examples illustrative of the general principles of the Science. By S. Earnshaw. 8vo. 3rd edition. Plates. Cambridge, 1845.

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A Treatise on the Differential Calculus, and its application to Geometry, founded chiefly on the method of infinitesimals. By Bartholomew Price. 8vo. Plates. London, 1848.

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Euclid's Elements of Geometry, chiefly from the text of Dr. Simson, with explanatory notes; together with a selection of geometrical exercises from the Senate-House and College examination papers; to which is prefixed an introduction, containing a brief

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| | outline of the History of Geometry ; with an Appendix containing additional notes on the elements, a short tract on transversals, and hints for the solution of problems, &c. By R. Potts. 8vo. Cuts. Cambridge, 1845-7. |
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| _____ | Peschel's Elements of Physics. Translated from the German, with notes by E. West. 3 vols. 8vo. Cuts. London, 1845-46. |
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| _____ | The Sugar Planter's Manual ; being a treatise on the art of obtaining sugar from the sugar cane. By Dr. W. J. Evans. 8vo. Plates and Cuts. London, 1847. |
| Kennard, R. W. | An Encyclopædia of Architecture, historical, theoretical, and practical. 8vo. 2nd edition. With a Supplemental View of the Symmetry and Stability of Gothic Architecture. By J. Gwilt. 8vo. 2nd edition. Cuts. London, 1851. |
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| Rankine, W. J. M. | Laws of the Elasticity of Solid Bodies. By W. J. M. Rankine. Tract, 8vo. Cut. No place or date. |
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| ————— | Report to Gen. Sir T. M. Brisbane, Bart., on the completion of the publication, in the Transactions of the Royal Society of Edinburgh, of the Observations made in his Observatory at Makerstown. By J. A. Brown. Tract, 4to. Edinburgh, 1850. |
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- Rowlandson, T. Report made to the Governor and Company of**
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Water for the Metropolis. By T. Rowlandson. Tract,
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- Simmons, Capt. R.E. Report of the Commissioners of Railways**
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- Smith, J. P. On the superiority of Macadamized Roads, for the**
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Birmingham, 1849.
- [Read at the Meeting of the British Association, Sept., 1849.]
- Société Centrale des Ingénieurs Civils. Mémoires et comptes-**
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| Stephenson, R. M. | Report of the Geological Survey of India, for the season of 1848-49, comprising,—I. General remarks. II. Geognosy. III. Description of plates and collections. Together with a list of heights above the sea, of the principal places referred to; also detailed maps and sections of the districts examined, &c. By J. McClelland. 4to. Plates and Maps. Calcutta, 1850. |
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| Stevenson, D. | Sketch of the Civil Engineering of North America, comprising remarks on the harbours, river and lake navigation, lighthouses, steam navigation, waterworks, canals, roads, railways, bridges, and other works in that country. By D. Stevenson. 8vo. Plates and Cuts. London, 1838. |
| Tate, T. | On the Strength of Materials; containing various original and useful formulæ, specially applied to tubular bridges, wrought iron, and cast iron beams, &c. by T. Tate. 8vo. Cuts. London, 1850. |
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| Vulliamy, B. L. | La Tribune Chronométrique; journal consacré aux intérêts, et à l'instruction professionnelle des Membres de la Corporation des Horlogers; par Pierre Dubois. 1 ^{re} année. 15 Janvier. No. I. Paris, 1851 |
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Collection of Charts published by the Admiralty during the past year.

MISCELLANEOUS.

Hardwick, P. Bust of Sir William Chambers, Architect.

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ADDRESS

OF

SIR WILLIAM CUBITT,

PRESIDENT,

To the Annual General Meeting, December 23, 1851,

ON VACATING THE CHAIR.

GENTLEMEN,

THE vote of thanks just passed so unanimously, is peculiarly gratifying to my feelings, as it is a convincing proof, that whatever may have been the result, my intentions have been fully appreciated, and that the close intercourse into which it has been my good fortune to be brought with many of you, during the two years for which, by your suffrages, I have had the honour of presiding over the Institution, has not diminished your kind feelings towards me.

In conformity with the bye-laws, the period has arrived for vacating the honourable post of President; and it is very gratifying to see proposed as my successor, a Civil Engineer, who, to his great experience, in important works of all kinds, and a firm and decided, but amiable character, joins the advantage of being some years my junior, so that he can serve you more energetically than I could; but with all these advantages in his favour, I cannot yield to him, or to any of my predecessors, the merit of more anxious desire than I have felt, to conduct the business of the Institution with dignity, or to maintain the position it has justly attained, amidst the numerous scientific societies of this great metropolis.

The last two years have been full of incident, but one grand feature,—"the Great Exhibition of the productions of Industry of all Nations"—absorbed the interest of the world. The nomination of the Royal Commissioners, the execution of the project, and the final and triumphant accomplishment of that remarkable undertaking, occupied exactly the period, during which it has been my good fortune to preside over the Institution, and my nomination as Royal Commissioner, being ex-officio as your President, it was a source of anxiety, that my individual acts should be such as you might approve. I have reason to believe, that in other quarters they have given satis-

faction, and if your commendation be added, the labours I have necessarily undergone will be amply repaid.

With respect to the progress of engineering works, since I last addressed you, and the actual state and prospects of the profession, much might be said; but I shall abstain from entering on so wide a theme, leaving a harvest of two years' growth for the sickle of my successor, who will, doubtless, reap it with his usual talent, for your benefit, and to his own credit; whilst from amidst the band of veterans, to whom you have been pleased to accord certain privileges, as 'Past Presidents,' I shall be content to glean some of the stray ears, which may be scattered from the solid sheaves of engineering skill, which he will lay before you. In thus abstaining from addressing you formally, I may perhaps incur the charge of being, to the last, an innovator; allow me, however, to assure you, that in the changes proposed by me, I have had only your benefit in view, and to the best of my judgment, I have not hesitated to do that which I conceived would be conducive to the general good.

In bidding you farewell, Gentlemen, as your President, allow me to offer my sincere thanks to the Members of all classes, collectively and individually, among whom I would include the Vice-Presidents, Members, and Associates of the Council, and Mr. Manby, our worthy talented and indefatigable Secretary, with all his excellent assistants, for the uniform support and assistance afforded me, in the Council,—at the Meetings, and at all other periods, and to express the fervent hope, that under a succession of Presidents, who may be more fitted for their duties, but who cannot be more anxious to perform them, than I have been, the Institution may flourish and become each year more useful to the world, and to the profession whose interests it represents.

January 13, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

The following Candidates were balloted for and duly elected:—

Thomas Brassey, Edward Alfred Cowper, Perceval Moses Parsons, and Captain Theodosius Webb, R. E., as Associates.

MR. RENDEL addressed the Meeting in the following terms, on taking the Chair for the first time after his election as President:—

GENTLEMEN,

IT has been for some years the custom with my predecessors, on first taking this Chair, to address a few words to the Institution, upon those topics which, though of general importance to the profession, could not be introduced into our Annual Report.

From this custom it is not my intention to deviate; for though there may be a certain amount of repetition in the subjects alluded to, and in the manner of treating them, yet the progress of Engineering science, and practice in two years, and especially in those just past, is such as to supply ample materials for observation.

But before proceeding with those remarks, let me offer you my thanks for the confidence which has placed me in the distinguished position of President of this Institution; though fully sensible of the honour, I could have wished that it had not been thought desirable to follow the usual routine, and that one more suited by ability and leisure had been selected; but I can, with confidence, promise the Institution, that my best efforts shall be exerted for its interest. I cannot hope to equal the untiring and unceasing devotion of my predecessor, Sir William Cubitt, but at least I will not spare myself, and I entreat the active co-operation, not only of the Council, but of the Members generally. With the confidence that it will be accorded, I quit this purely personal subject, and proceed with the few remarks I have to make, on what is generally interesting to us as a body.

Even if it were not a matter of great and lasting importance I could not, as an Engineer, and the successor of Sir William Cubitt, pass over, without notice, the Great Exhibition.—Its wonders, and the effects they are likely to produce, have been so ably and fully dwelt on elsewhere, that I will not even touch on them here, but I am sure you will all agree, that our warmest thanks are due to our late President, for the admirable way in which he represented us as a body, during the construction of that marvellous building.—We have reason to congratulate ourselves, that we had amongst us one so able, and so earnest; and who had the power, as well as the inclination, to devote himself so entirely to his work. You have heard, from the Report of the Council, the services also rendered to the cause, by other Members and Associates of our body; indirectly our Members generally may claim to have assisted, by the increased facilities of communication their labours have afforded; without which facilities, we may venture to assert, that the Exhibition would not even have been possible.

But from the Exhibition itself we Engineers, and particularly those among us, whose attention is more especially devoted to the mechanical branch of the profession, might read a valuable lesson: confined to the useful, as were the specimens of her produce, there was no part of the Exhibition demanding the attention of the Engineer more than that allotted to the United States of America, and that, not so much from what she exhibited, as from what she

withheld ; we saw there, the raw material and the manufactured article, and the question necessarily arises, how with her deficiency of population does she convert the one into the other? The answer is, by the universal application of well-adapted machinery ; and it would have been well too, had the artizans of this country marked the successful operations of the mind, in overcoming the want of labour ; how the manufacturer, deprived in some degree of manual assistance, studies to supply the deficiency by machinery : in a word, they might have learned the inevitable result of combination against capital.

The same warning should be taken from the Continent, now gradually emancipating itself from dependence on England, for her manufactures ; showing us the necessity of increased energy and of harmony between the employer and the employed, if we would maintain even our present position.

Deeply, however, as we are interested in the progress of Mechanical Engineering, it is that branch of the profession, in which mechanical skill occupies a comparatively subordinate position, that it is our immediate province to consider.

The occupation of the Civil Engineer has been aptly designated " the application of mind to matter." This is a comprehensive phrase ; but it is literally correct, and the individual history of the Civil Engineer shows, that mere technical knowledge of the details of a work, however critical and correct, will not lead to distinction. All undertakings must be examined with comprehensive views of their ultimate effects, not only as regards the immediate projectors and the present time, but on society generally and on the future ; and those men, in our own time, who have so regarded their professional engagements, have attained the highest positions and reaped the most solid rewards.

The cursory review then of those works in which Civil Engineers have been engaged, almost assumes the character of a narrative of the commercial, nay in some measure, of the political, progress of nations.

The principal works in which, in these days, the aid of the Civil Engineer is required, are, railways, harbours, docks, bridges, the improvement of rivers, the formation of canals, the drainage of low-lands, the supply of water to towns, and their sewerage.

All these have a direct and beneficial bearing upon the health and prosperity, morally, physically, and commercially, of a nation.

I well remember the pardonable pride with which our first President, Telford, in addressing the Members, used to descant on the beautiful roads he had constructed through mountainous and difficult

countries; and upon the lines of canal he had formed, their aqueducts spanning valleys with a daring which emulated the greatest works of the Romans. How would he have rejoiced to have seen our time, when, within a few years, there has been commenced and developed a system of railroads, covering the face of Great Britain from Aberdeen in the north, to Plymouth in the south; and spreading its ramifications into nearly every county! This net-work of iron now extends over 7,000 miles. The capital expended has been upwards of £235,000,000, whilst the receipts for passengers and goods conveyed in one year, ending 30th June last, amounted to upwards of £13,750,000.

Such has been the result of the railway system in this country since 1830, when the late George Stephenson, of undying fame, completed the Liverpool and Manchester line.

Whether we regard these facts, as evincing the wealth, the enterprise, or the commercial necessities of this country, they are alike wonderful; and the more so when it is considered, that of the £13,750,000 received from traffic, nearly one-half is for the conveyance of goods, whilst the average amount of traffic, on our canals and turnpike roads, has not been materially diminished. It is thus evident, that the introduction of railways has developed the productive capabilities of new districts, and thereby added to their wealth. The great proportion of third-class passengers conveyed on railways, affords also a proof, that the possession of the means creates a desire amongst the poor, as well as the rich, of communicating with their fellows to the benefit of all.

Whilst on this topic, we must not forget the great facilities, thus afforded, for postal communication; four hundred millions of letters are now conveyed annually, instead of seventy-six millions, which was the number before the establishment of the penny-post system. Steam alone could afford the means of conveying such a mass of correspondence.

The majority of the railways, completed within the last two years, have been branches, or the extensions of main lines, such as the Great Northern, which will, it is presumed, be opened to York in the course of the present year; and of which it is only just to say, that the excellence of its construction, and the simplicity of the works, are alike creditable to the skill of Mr. Joseph Cubitt, the Engineer.

The prolongation of the South Wales line, by Mr. Brunel, is a great step, bringing an important mineral and manufacturing district almost to the gates of the metropolis. On this line, the remarkable structure of the Chepstow Bridge deserves particular

attention, presenting, as it does, a combination of the suspension principle, with girders of plate iron of a peculiar section, derived from the results of Mr. Stephenson's experiments, as to the proper strength for tubular girders. •

The only link wanting in the railway chain of the North West Coast, was that between Ulverstone and Lancaster. It is now being supplied; by the formation of a line, in connexion with the Furness railway. The difficulties anticipated, in traversing the shifting sands of Morecambe Bay, had hitherto deterred projectors from this undertaking, but relying on the facilities offered by Mitchell's screw piles, for obtaining firm foundations, in the most treacherous strata, Mr. M'Clean, the Engineer of this, as of the Furness line, has not hesitated to direct the works to traverse the Bay, intending to employ these screw piles for bridging the estuaries of the Rivers Leven and Kent; whilst in connexion with these works, by a suitable arrangement, about thirty thousand acres of land will be reclaimed from Morecambe Bay, and the navigation will, it is presumed, be materially improved.

The Royal Border Bridge, opened by Her Majesty, August 29th, 1850, and the High Level Bridge, inaugurated by His Royal Highness Prince Albert, in the same year, are both works whose boldness of design and solidity of execution are worthy of the skill of Mr. Robert Stephenson, their designer.

The wonder of the age, the tubular bridge across the Menai Straits, which has been finished since the address of my predecessor, might perhaps be considered as a subject to be adverted to here in detail; but all that was then hoped has been so fully realized, in the splendid success of Mr. Stephenson's anticipations, that it needs not the mite of my praise, and it would be useless to add to descriptions already so ably given.

At the new bridge at Rochester, our late President, Sir William Cubitt, has tried an ingenious system of sinking large cast-iron cylinders, to form the foundations of the piers. The detailed account of this successful innovation on the ordinary modes of bridge building, which has been so recently before the Institution, has satisfactorily demonstrated the essential utility of the system, for peculiar localities.

The main lines of railway in Ireland have been chiefly constructed under Sir John Macneill and Mr. Hemans, and on them some fine works have been executed, and some judicious improvements introduced. The viaduct near Newry, recently built, under Sir John Macneill, may be particularly mentioned, for its graceful proportions, the simplicity of the design, and the solid manner in

which the blocks of Newry granite have been assembled in its construction.

Starting from Dublin, the main lines have advanced towards the north, as far as Newry; whilst the enterprising city of Belfast has commenced her own lines: Cork and Waterford, in the south, are united with the capital, and a branch to Limerick brings the railway to the banks of the noble Shannon, with her improved navigation. A line is formed to Galway, in the west, and attention has been much directed to a proposition, for a communication from thence to the United States, by the establishment of a line of first-class steam-vessels.

In our Colonies the railway system is extending, although up to the present time only by short lines, offering a prospect of immediate return. In British North America a railway has been projected, to extend from Halifax, on the Atlantic, to the shores of the Pacific, to be constructed on the principle of colonizing the lands on either side; thus creating a population and traffic for the line, as it advances.

In India two lines of railway have been commenced, with every prospect of success, being under the patronage of the Indian Government, the works conducted by English Engineers, and executed by English contractors, most of whom are connected with this Institution.

Our Associate, Mr. R. Macdonald Stephenson, the first projector of these lines, went to Calcutta in 1843 for the purpose of directing the attention of the Indian authorities to the value of railway communication, in such a country and climate. After encountering the labour and vexation, always attendant on what is commonly called "innovation," he succeeded in establishing the practicability of a line from Calcutta to Delhi, a distance of upwards of eight hundred miles, and in showing, that such a line, whilst it promised to open up new, as well as to increase the present commercial resources of the country, would also stimulate the natives to fresh exertions, and reduce the machinery of government. Above all, that it would hasten the accomplishment of the great mission, which our rule over the millions of our fellow-creatures, inhabiting that vast region, has imposed upon us, of raising them from an almost animal, to an intellectual condition.

Mr. R. Macdonald Stephenson is now the Resident Manager for the East Indian Railway Company, in the construction of a line of one hundred and twenty-one miles, connecting Ranegunge with Calcutta, forming the first section of this great railway. Associated with him is our Member, Mr. George Turnbull, as the principal resident Engineer, assisted by several others of our Members and Associates, under my direction, as Engineer-in-chief.

Whilst these works are advancing prosperously on the eastern side of India, Mr. James Berkeley is, with equal promise of success, carrying out a line from Bombay to Tannah, a length of about twenty-one miles; and it is not too much to hope, from the support which these experimental lines are receiving from the Indian authorities, that they will, ere long, form one great trunk line, connecting the chief seats of Government with each other, and extending into the north-west provinces, as far as Delhi; a distance of fifteen hundred miles, traversing districts of great fertility, rich in minerals and prolific in the production of many of the raw materials employed in our staple manufactures. A large field is thus opened, for the useful employment of the superabundant capital of our enterprising countrymen, and for the skill of the profession, which it is the privilege and the duty of this Institution to foster and advance.

Our excellent Vice-President, Mr. Robert Stephenson, with Mr. Borthwick, Mr. Swinburne, and a staff, comprising a number of our members, is now engaged in confronting the difficulties of carrying a railway into Egypt, across the hitherto comparatively impracticable Desert, facilitating the transit to such an extent, that in conjunction with the continental lines, and improved steam navigation, our Indian possessions will soon be within an easy distance, instead of, as formerly, requiring several months to reach them. In this great work, amidst the remains of the gigantic labours of ancient engineers, we may anticipate, not only the extension of our friend's well-earned reputation, and that of the thoroughly English profession of Civil Engineering, but we may reasonably hope, that the establishment of railways will introduce to that once great country, the blessings of high civilization, and all the social and moral advantages that inevitably follow.

The line, proposed to be executed, extends from Alexandria to Cairo, and its course will probably pass over the works for the 'Barrage' of the Nile, now executing under Mougél Bey, a French Engineer, in the service of the Pacha.

On the Continent generally, railways are making a steady, and in some countries a rapid progress. In France, political events are acting in some measure as a check; but there is no doubt, that should permanent tranquillity be restored, and her great trunk lines be completed, the mass of the traffic between England and India, must avail itself of them.

In Belgium, so many lines were executed simultaneously, that little remains to be done beyond the establishment of branch railways.

In Germany, steady progress is made with the main lines, and the

most important cities are being gradually brought into communication with each other.

In Austria, great attention is being paid to the Vienna and Trieste line. Sardinia and Piedmont are also making progress, and in a short time, the traveller to India will be able to choose between three routes, in his passage through Europe.

In Russia, a line between Moscow and St. Petersburg is open ; and another between St. Petersburg and Warsaw, a distance of six hundred and eighty-three miles, is commenced. In that country, much is being executed under English Engineers. Mr. Tierney Clarke has completed a Suspension Bridge at Pesth, and Mr. C. Vignoles is now engaged on one at Kieff.

In Norway, a railway forty-three miles in length, is in rapid progress, for the purpose of improving the communication between Christiana and Trondheim. There are many interesting points connected with the working of Railways in such a climate, a detailed account of which has been promised by Mr. Bidder, the Engineer of the line.

On all these Continental lines, it must be observed, that though at their commencement the English system was generally adopted, English locomotives and carriages used, and in many cases the work undertaken by English contractors, yet a short time has sufficed to emancipate them from dependence on this country, and with our tools, and their own native talent, they, in many instances, successfully compete with their tutors.

It is, however, in the United States of America, that the railway system has been most rapidly developed. Feeling the necessity of traversing their almost boundless plains, and piercing their dense forests, the Americans did not wait for the perfecting of the system, but adapting their wants to their means, began by laying down squared logs, on which were spiked flat bars of iron for rails ; the viaducts were timber piles, carrying these primitive and inexpensive rails ; the engines were so constructed as to traverse sharp curves, and ascend steep inclines ; whilst their cars were made to convey the largest number of passengers, in one vehicle, and on one set of wheels ; now, however, whilst this old pioneering system still, to some extent, continues, what a change has been effected on the main bulk of the railways ! Substantial works have been constructed, permanent rails have been laid, efficient engines and most complete cars have been provided, and in 1851 the length of railways in the United States, was calculated to be upwards of nine thousand seven hundred miles.

In conjunction with this extensive development, must be men-

tioned the name of Major-general Gibbs MacNeill, who may be termed the pupil of Telford and George Stephenson. By him were designed upwards of two thousand six hundred and fifty miles of internal communication, of which he superintended the execution of eight hundred and eighteen miles, whilst of the remainder, a large portion is now in progress, and the whole will eventually be executed.

The Americans are also rapidly solving the problem of the passage of the Isthmus of Panama, by establishing a line of railway, which is partly constructed, so that already a portion has been used in the transit of passengers, specie, and merchandize; and as the railway will be completed in 1852, it will be ascertained, whether the natural impediments to the formation of a ship canal, are as formidable as had been anticipated.

Closely in connection with the subject of the progress of railways, is that of the electric telegraph. This means of communication is now so generally employed, that a railway is scarcely considered safe, on which it does not exist.

In the United Kingdom, the Electric Telegraph Company has about three thousand miles in operation, and our member, Mr. Edwin Clark, is still actively engaged in its extension. The communication with the Continent being now perfected by the Submarine Telegraph, a few seconds suffice to convey news between London and Paris, and in a short time, by the extension of the continental lines, intelligence from our remotest possessions will arrive with almost fabulous speed.

The establishment of a connexion between the Greenwich Observatory, and the telegraph wires, is an important step for facilitating simultaneous observations, not only in Great Britain, but also on the Continent, and which, under the direction of our Honorary Member, Professor Airy, must materially aid the cause of astronomical science.

The principal marine works in progress are the Docks at Liverpool and Hull, by Mr. Hartley; at Sunderland, by Mr. Murray; at Hartlepool, by Mr. Simpson; at Plymouth, by Mr. Brunel; and at Grimsby and Leith, by myself. There are many novel and important points connected with all these works, which I hope we shall shortly see brought before the Institution, by their respective engineers. Amongst the Harbours of Refuge, the most important in progress are those at Harwich, at Alderney, and at Jersey, under Messrs. Walker and Burges; and at Holyhead and Portland under my own direction. The Pier at Dover, by Messrs. Walker and Burges, should also be noticed, as forming a portion of the new Harbour of Refuge. This work, as well as that at Alderney, is remarkable for the extensive use made of large moulded blocks of

concrete and rubble masonry of uniform size, for facilitating the operation of setting, by means of diving apparatus. In addition to the Government works at Jersey, the States have, from their own funds, made great progress in the formation of an extensive harbour at St. Heliers, designing ultimately to establish a dock for large shipping and steamers.

At Harwich, under the direction of Messrs. Walker and Burges, a Breakwater, 500 yards in length, has been erected, and extensive dredging operations are being carried on, by which a depth of 18 feet at low water, and 30 feet at high water of spring tides, will be obtained.

The works at Portland are interesting in a social point of view, from the employment of convicts in the quarrying operations, an experiment of great importance at this time, when the proper disposal of our criminals is so difficult. The method of construction is peculiar, being carried on from an extensive stage, formed of piles, shod with Mitchell's screws, by which they are enabled, in spite of their great length (nearly 80 feet), to be inserted with great rapidity and economy.

The Holyhead works are remarkable for the rapidity of their progress, 600,000 tons of stone having been quarried and deposited in the breakwater, during the past year, being at an average rate of more than 200 tons per working hour. The introduction of the system of mining, applied by our late President, (Sir William Cubitt,) some years ago, to the removal of the Round Down Cliff, has much facilitated these operations, in which we have been efficiently aided by General Sir John Burgoyne, and the late Captain Hutchinson of the Royal Engineers, whose accidental death, while superintending one of the early experiments, we have all to deplore.

Lowestoft Harbour, though it has been completed for some years, demands notice at this time, from the fact that it is becoming a most valuable Harbour of Refuge, as well as a commercial port of consideration. Here, we have another evidence of what can be effected by the combination of skill and capital. Mr. Bidder, in looking for a suitable coast terminus of the lines of railway connected with the Eastern Counties, adopted Lowestoft, whilst Mr. Peto, with his usual foresight, furthered the measure, by the application of his great energy and means. The result is, that not only a most useful Harbour of Refuge has been formed, on the Eastern Coast, where it was much needed, but that a new commercial connexion has been opened with Norway, whilst a thriving town has sprung up, upon a spot, where, a few years ago, all was comparative barrenness. Lowestoft is thus eventually destined to fulfil the expectations of our first, as well as of our last President.

It may be regarded as somewhat foreign to the object of this address, to refer to the state of Steam Navigation. But that subject is so intimately connected with all the principles which should govern the selection of sites for harbours, the arrangement of their works, and the termini of railways, that I feel it impossible to record my views on these subjects, without shortly adverting to the marvellous progress made in the last twenty-five years, not only in the number of steam-boats, and the extension of their application to the armed and commercial services of the country, but also to the influence which their increasing size has had, in producing a corresponding increase in the dimensions and capabilities of the general commercial shipping of the world.

By returns lately made, it appears, that the number of steamers, in both marines, belonging to Great Britain, amounts to upwards of one thousand seven hundred, with an aggregate burden of more than 250,000 tons register. By four great Packet Companies alone, no less than sixty-four steamers of the largest class are in use, with an aggregate nominal propelling force, represented 30,000 H. P., employing directly and indirectly an enormous capital, and requiring the services of a large number of the most intelligent class of operatives and seamen.

The most interesting application of steam power to navigation, is that of the screw propeller, as an auxiliary to sails, a use which seems destined to work as great a change in goods traffic, on the ocean, as railways have effected on the land; whilst the general tendency appears still to be, towards increasing the dimensions and power of steam-vessels destined for long voyages.

This fact must be gratifying to our Vice-President, Mr. Brunel, who in 1836, advised the building of the Great Western, the dimensions of which were then considered so excessive, that in 1838, when she made her first voyage to New York, her safe return was the last thing expected; and again, when the further advance was made by him in 1845, in building the Great Britain, an iron vessel propelled by a screw, the nautical world was equally sceptical.

From the United States we hear of great progress in steam navigation, and of great velocity being attained, especially in river boats.

An authentic account of steam navigation generally in that country, would be most valuable to the Institution. And as an interesting American communication has been before us this Session, we shall hope to have many more from our Transatlantic brethren.

Public attention has been much directed to the improvement of rivers, not only for navigation, but as affecting the drainage of the

country. At the present moment, changes are taking place in the Thames, and most of the principal rivers, which afford invaluable opportunity for observations, on the effects rivers can produce, by their own action, and also on what is done by the passage of steam-vessels, in keeping the lighter silt constantly in motion.

The improvements in the Clyde are progressing on the same system as was originally begun there by Smeaton, and with unflinching success.

In the Rivers Ribble, Lune, and Forth, Messrs. Stevenson, of Edinburgh, have pursued, with great success, the same system of improving their navigable channels; of which an interesting account has been published by Mr. David Stevenson.

With the improvement of rivers, there is intimately connected a question of vital importance at present; it is the effect produced on streams, by the great extent of land drainage, and other agricultural improvements.

Mr. Walker in the Middle Level, and Sir John Rennie in "the Great Wash," will succeed in warping, embanking, and reclaiming, several thousand acres of land, which will add a new district to the east coast of England.

It is gratifying to perceive the increased attention to sanitary measures in our towns; and whilst admitting how bad our state has been, it cannot be denied, that measures of improvement have been commenced.

The piercing of new streets in the metropolis has occasioned the destruction of many localities, where the indigent population congregated, to their own detriment, and the demoralization of the neighbourhood. The reconstruction of whole districts, at the east end, of a class of dwellings fitted for the labouring classes, has been productive of the most beneficial effects, physically and morally, and it is certain, that a little exertion on the part of the rich, will sooner, or later, be amply repaid, by the amelioration of the classes dependent on them.

The general sewage of cities and towns, is in a transition state, no comprehensive system being decided on; but, meanwhile, certain progress is making, and it is to be hoped, that as far as the Metropolis is concerned, our noble river will ultimately be freed from pollution, and its consequent ill effects.

The water supply of cities and towns is a great question, now being practically essayed.

In the Metropolis, Mr. Simpson, our Vice-President, has taken the lead, by establishing the New Lambeth Works, at Thames

Ditton, twenty-three miles above London Bridge, and far above the probability of any pollution of the stream.*

It is the intention of the Chelsea Water Works Company to introduce a Bill, during this session, for the establishment of similar works, drawing water from the same locality; whilst the River Lea Trustees are also about to apply for powers, to construct reservoirs of great magnitude, to receive the surplus water of the Lea, and its tributaries, above Hertford, also, with a view to the supply of London. There are several other plans for the supply of water to London, and its environs, and all will, doubtless, undergo a strict examination, in the approaching session of Parliament.

At Bristol, at Liverpool, at Manchester, at Newcastle, and in several other places, Mr. Simpson has introduced great modifications, and successfully applied both the intermittent and the constant supply systems. Of this latter system our member, Mr. Hawksley, has been one of the most earnest advocates, and at Nottingham, and in other towns, he has satisfactorily applied it. His comprehensive scheme, proposed for the supply of Liverpool, is understood to have been commenced.

At Manchester, the great works executing by our member, Mr. Bateman, for the Corporation, may be quoted for their extent, and the careful arrangement of the details.

The Dundee Works, by Mr. Leslie, are also interesting from their compactness and success.

The Edinburgh Water Works, now nearly completed, under my own direction, are very extensive. There are eight reservoirs with a collective content of nearly 170 millions cubic feet; and the supply for the city is upwards of 30 gallons per day to each individual, besides a large distribution to distillers and other wholesale consumers.

Within a short time two curious mineralogical discoveries have been made in this country.

In the neighbourhood of Middlesborough-on-Tees, a bed of iron ore has been found, close to the surface, and of about 15 feet, to 18 feet in thickness, producing from 33 to 35 per cent. of excellent iron. The credit of its discovery is due to our Associate Mr. Vaughan, who traced its course from the out-crop, near the sea, to the main bed, which is now being extensively worked for the iron furnaces around, and for shipment. This discovery will probably

* During the delivery of this address, information was received of the water pumped up at Thames Ditton having, for the first time, reached the reservoirs at Brixton.—*Sec. Inst. C. E.*

lead to important changes in the iron trade, similar to those produced by the use of the Black Band in Scotland.

Mr. Blackwell, of Russell's Hall, near Dudley, whilst collecting mineralogical specimens for the Great Exhibition, observed near Northampton, indications of the existence of iron ore, which eventually proved to be a vein, upwards of 12 feet in thickness, consisting of brown peroxide of iron, lying close to the surface in the lower oolitic formation; where it can be easily quarried. By analysis, it is found to yield from 30 to 42 per cent. of metal, free from any injurious admixture; and if due facilities are afforded for its transport, by the South Midland Railway, to the Staffordshire coal district, it must eventually prove very beneficial to the iron trade of the country.

The infinite variety of interesting topics, arising on all sides, has extended this address far beyond its intended limits, and I must request your indulgence for having so exercised your patience. In all the works alluded to, you will have observed, that our members have been actively engaged, and we may thence view with pride, our utility as a class, and see how large a field still lies open before us; whilst if there be only the same amount of kindly feeling among us, as has hitherto existed, and if we meet constantly in this Institution, for the friendly interchange of opinions, and mutual advice and assistance, we shall augment our individual prosperity, whilst we execute our several tasks in the great scheme of creation.

Being duly moved and seconded, it was resolved, 'That the President be requested to permit his Address to be printed and circulated with the Minutes of the Proceedings.'

After some observations by Mr. Locke, M.P., V.P., Mr. Scott Russell, and General Gibbs MacNeill, on the topics touched on by the President in his Address, Mr. J. B. Redman explained the method he had adopted in the examination of the South Coast of England, in order to afford the members an opportunity of being prepared for the discussion of his paper on that subject, at the next Meeting.

January 20, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 784. "On the Alluvial Formations, and the Local Changes, of the South Coast of England." By **JOHN BALDREY REDMAN**, M. Inst. C. E.¹

FIRST SECTION.

FROM THE RIVER THAMES TO BEACHY HEAD.

THE passage of shingle along the coast of England, due, as is generally believed, to the action of waves alone, takes on the south coast, a course from west to east, and on the east coast, from north to south; during certain winds, the shingle is heaped up coincident with their direction, and repeated withdrawals and renewals (the latter being the most frequent), cause a leeward movement of the material, in a series of triangles, of which the shore is the base, as has been shown by Colonel Sir W. Reid² and Mr. Palmer;³ this leeward progression is due, on the south coast, to the prevailing winds, and on the east coast to its position.

These results have been attributed, by some writers, to the tides and currents; and it is worthy of notice, that supposing the currents to be a sufficient cause for these phenomena, the same results would be produced from the particular configuration of Great Britain, and the course of the tidal wave. Should any natural, or artificial projection intercept this motion, an accumulation, which will increase, or be held in check, according to the state of the winds, takes place, up to a certain point, or until the angle formed is filled up; when the shingle will pass round, most probably across the entrance of a harbour, if in deep water, and again travel in the prevailing direction: numerous examples occur which, it is thought, corroborate this view. The groynes along the south coast afford, also, to a certain extent, corroborative evidence; for when they are not carried far enough inland, the shingle passes round the back of them, and when they are not sufficiently projected seawards, it travels round their extremities; but by far the most common action is, unless the groyne is of great height, or short length, for the shingle, after accumulating on the weather side, to the level of the top of the

¹ The first section was read at the meeting of December 16, 1851, but the two sections are printed together; and an abstract of the discussion, which extended over a portion of three evenings, is given consecutively.

² Vide Royal Engineer Corps. Papers, vol. ii., p. 129.

³ Vide Phil. Trans. Royal Society, 1834.

groynes, to pass over it and travel to leeward, which, like the progressive motion round a fixed point, is one of degree, and not easily estimated. It is difficult to fix any limit, by which shingle would be prevented, under certain circumstances of position and shelter, from passing over an obstruction: this is particularly apparent in the case of the Chesil Bank, where, upon a clay formation, the shingle has attained the extraordinary height of 30 feet above high-water mark of spring tides, the largest pebbles being generally to leeward and at the summit.

On the south side of the mouth of the Thames, great changes have taken place, more especially along the north shores of the Isle of Sheppy, as has been shown by Sir Charles Lyell¹ and other authors.

The chalk promontory of the Isle of Thanet² must have yielded a constant supply of shingle for many years, though, when the number of veins of flint in these cliffs is considered, perhaps to no very great extent. Around the island, there is comparatively little shingle, the foreshore being invariably composed of a fine sand, bounded, near low-water mark, by clay; at Ramsgate, the sand has increased seaward to a considerable extent. Smeaton³ described the shingle as travelling from the eastward, and it is curious that along these shores, very little shingle is seen; and if that produced by the Isle of Thanet, after being carried into deep water, as it undoubtedly must be, is driven past Ramsgate, to the westward, it is probably thrown ashore in the neighbourhood of Deal, and joining the western supply, again travels eastward—an instance among other examples hereafter to be referred to, of this material travelling, under certain circumstances, at a limited depth below low water.

In heavy weather, local appearances in this neighbourhood seem to show, that the shingle is either washed up from a considerable depth, or else passes round in deep water. During the winter of 1847–8, a small collection of beach, which was generally supposed, from the appearance of the flints, and other causes, to have come from the westward, was formed upon the sands, near high-water mark, immediately to the eastward of Ramsgate Harbour. At

¹ Vide Lyell's *Principles of Geology*, 1840.

² Vide Batteley's *Richborough and Reculvers*, 1774; Kilburne's *Survey of Kent*, 1657; Lewis' *Isle of Thanet*, 1736; Boys' ditto, 1794.

³ Vide Smeaton's *Reports*, vol. iii., p. 82, 1812; Hasted's *Historical and Topographical Survey of Kent*, 1797; Fuller's *Worthies of England*; Goodwin *Sands*, 1662.

Kingsgate, black flints, rounded by the action of the water, and bearing the appearance of being supplied from the neighbourhood, are collected in several places, by the north-east winds, and may possibly be brought up from a considerable depth, though not so great as to be out of the influence of the waves.

Immediately to the west of Ramsgate, along Pegwell Bay, and Sandwich Flats, to Shingle End, there are no traces of shingle, on the immediate line of the shore. The indentation of Pegwell Bay has promoted deposit for many years, and the clay cliffs forming its margin, have suffered great waste. Sandwich Flats have experienced a corresponding increase, from the deposit of this material, aided by matter brought down by the River Stour, whose course is almost as tortuous through the flats, as it is through the marsh lands.¹

The western side of Pegwell Bay has formed a trap, during a long period, for the collection and retention of shingle; the spit termed "Shingle End," which is the north-east termination of the general western belt, has gradually increased to the northward; for from maps of the time of Elizabeth, Sandown Castle appears to have been situated at its extremity, and took its name from the sand hillocks, which preceded the accumulation of shingle on the shore.

The low shore, from Sandown Castle to Deal, and thence to Walmer, is bounded by extensive "fulls" of beach, and the cliffs to the westward, by Kingsdown, St. Margaret's, and the South Foreland, to Dover, have at the foot a shingle beach, which has been much increased, in the neighbourhood of Kingsdown, during the last half-century.

It is supposed by antiquarian authorities, that Dover Harbour was formerly an estuary of the ocean, which flowed up a valley between the chalk hills. This opinion was formed from the descriptions of the spot by Cæsar and Antoninus,² and from remains which have been found in different excavations. Leland,³ Camden,⁴ and Somner⁵ refer to these authorities and to the practical evidences for such deductions. From such evidence it appears, that at an early period there was no shingle at all at Dover, as might have been supposed, and which there is historical evidence to prove was the case; its gradual advance from the westward, eventually blocked up the entrance, and penning up the water, an uncertain channel was formed at low water; piers and jetties were afterwards erected, to

¹ Vide Boys' History of Sandwich, 1792.

² Vide Burton's 'Commentary on Antoninus,' 1658.

³ Vide Leland's 'Itinerary,' 1539.

⁴ Vide Camden's 'Great Britain,' 1551.

⁵ Vide Somner's 'Roman Ports and Forts,' 1599-1668, published 1693.

preserve a permanent outlet, and groynes were constructed on each side, to retain the shingle, and to render that a permanent barrier, which had hitherto been of a fluctuating character. Dover was thus, in its primary elements, similar to Yarmouth, Shoreham, and other harbours formed by the penning-up of land, and tidal waters, by a mole of shingle; but at Dover, the natural features of the harbour are now, to a great extent, concealed by works of art.

The plans contained in the Cottonian collection, at the British Museum, referring to the reigns of Henry VIII. and Elizabeth, throw much light upon this interesting subject, and clearly show the numerous works that were executed, at those periods, for the purpose of protecting the entrance from the travelling shingle.

Captain Perry,¹ the well-known engineer, who visited Dover in 1718, and made an elaborate Report upon the harbour, referred to the manner in which it was choked up with shingle by the westerly winds, and proposed low-water groynes, or jetties, and an extension of the west pier, to cure the evil.

One remarkable passage in that Report refers to the effects produced by falls of cliff to the westward, which arrested the beach so long, that the requisite supply for the protection of the Dover works was wanting, and these obstructions were actually blown up by the inhabitants, in order that the beach might travel on as heretofore.

In 1769, Smeaton² proposed an extension of the west pier, to arrest the beach; but at the same time gave, as his opinion, that no extension of the pier would totally prevent the shingle from travelling round into the entrance.

In 1782, Nickalls proposed, that the pier-heads should be extended for a distance of 200 feet, by which, he expected, the pebbles would be driven into deep water; though as this was uncertain, he recommended that sluices should also be provided.

In 1802 Messrs. Rennie and Ralph Walker recommended an extension of the piers; and the further they were protruded, the less beach, they anticipated, would lodge at the entrance. It would appear, from the Report of those eminent engineers, that they were of opinion, that shingle was acted upon by the currents, as well as by the waves of the ocean.³

In 1812 Mr. Ralph Walker reported alone, and recommended an

¹ Vide Perry's Daggengham Breach, &c. 1721.

² Vide Smeaton's Reports, vol. iii., pp. 140, 141, 1812.

³ Vide Lyon's History of the Town and Port of Dover, &c., 1813; Mantell's Cinque Ports Meetings, 1811; Worthington on Dover Harbour, 1838.

extension of the south pier to low-water mark, which he considered would tend to carry the beach past the entrance.¹

The mouth of the harbour appears, subsequently, to have so constantly suffered from the accumulation of shingle, particularly in the winter of 1833-4, that Mr. Telford was consulted by the Duke of Wellington. The works planned, and partly executed by that engineer, and subsequently amplified and extended by Mr. James Walker, are well known.²

The additional sluicing power, thus obtained, held the bar in check. From the extension of the works at Folkestone, the erection of groynes in front of the railway works, and the falls of the cliff to the westward, the same result has occurred, that was complained of prior to the Report of Captain Perry; the beach being so arrested to the westward, that the requisite supply to make good the amount of loss, caused by the travelling of shingle to the eastward, is wanting, and the harbour works and lower town are deprived of their natural barrier. The same effect was experienced upon the completion of Cheeseman's Head, a pier to the westward of the harbour; and that work was partially pulled down, in consequence of remonstrances from the owners of property in the bay, the frontage of which is now partially defended by a sea-wall. It is impossible, from the various artificial works to the west of Dover, to arrive at any conclusion, as to the effect of a deep-water pier upon the travelling of shingle; and the tenor of the eminent opinions, hitherto given, as well as the conclusions to be drawn from the evidence before the Harbours of Refuge Commission, respecting Dover Bay, appear to lead to this result, that after a certain accumulation has taken place, the shingle will pass in deep water.

The first, or land kant of the Breakwater, now erecting to the westward of the harbour, and which projects 540 feet beyond low-water mark, or 670 feet beyond the high-water mark, on the Railway Wharf, will hereafter elucidate this subject; at present the shingle has apparently been arrested to the westward from other causes.

The erection of groynes to the westward of Dover, has insured a large collection of beach; but eastward of Folkestone, from the extension of the harbour works there, a corresponding deficiency

¹ Vide Jeake's *Cinque Ports*, 1678, edition of 1728; Darell's *Dover Castle*, 1786; Lyon's *History of the Town and Port of Dover, &c.*, 1813; Mantell's *Cinque Ports Meetings*, 1811; Worthington on *Dover Harbour*, 1838.

² Vide Telford's *Works*, 1838.

has occurred. The artificial works of Folkestone Harbour, must for a time have arrested the beach; but being of small projection, the shingle soon travelled round, and it was no uncommon sight, seventeen or eighteen years since, to see the fishermen excavating a channel, at low water, through the beach, as without such a means of egress their boats were blockaded within the harbour. A horn-work, or groyne, which has recently been considerably extended, was originally projected from the south-east extremity of the pier, and no doubt, for a time, protected the entrance. The effect of this further extension is, a vast accumulation of shingle along the southern and western frontage of the harbour, and in front of the railway buildings, affording an admirable example of the action of a work of this description; for the mass of shingle, which now fronts the harbour works, and is level with the top of the pier, gradually decreases in breadth, and falls slightly to the westward, until it becomes of the average width, at the foot of the cliffs, or it may, perhaps, be more properly said to change its direction.

The beach has assumed a more south-easterly direction, as the groyne has been extended, lying in two distinct "fulls," with two intermediate ridges: the effect upon the eastern side of the harbour has been a complete removal of the shingle, which only reappears again at Cock Point and Ledge, to the east of the harbour and the west of Eastware Bay.

At Sandgate, the groynes on either side of the circular stone tower, erected by Henry VIII., retain a large "full" of pebbles, forming a projecting point beyond the general line of the beach, which does not appear to have been much changed of late years; for Fussell,¹ in his description of this tower, in 1817, says the sea washed the base of it, which it does now, in high tides; he also says, that the outworks of the battery were reduced, on account of the encroachments of the sea; showing that since the time of Henry VIII., the beach has been lessened. Here, as elsewhere, the largest pebbles are thrown up to the top of the "full," about 3 feet above high-water mark of spring tides.

Mr. Palmer, in his Paper on Beaches, has fully explained this action.

At Shorncliff Battery, to the west of Sandgate, a large accumulation has been produced by the groynes, erected by the Government for its protection; but the coast to the eastward has suffered, for the usual supply being cut off, the highway bordering upon the coast was entirely destroyed, rendering necessary the construction of

¹ Vide Fussell's Coast of Kent, 1817.

esplanade walls; when, however, the shingle had accumulated at the groynes, so as to overtop them, and to pass again to the eastward, this work became buried in shingle, in which state it has remained up to the present time. The sluice outlet to the Royal Military Canal, is also completely buried in shingle; and the beach west of this, in many places, covers the saltings, between the shore and the canal, which latter is thus threatened with a similar fate to Hythe Haven, in the bed of the channel of which, the east end of the Royal Military Canal is most probably formed.¹

Leland, Camden, Lambarde,² Somner, Burton, Stukeley,³ Campbell,⁴ Boys,⁵ Reynolds,⁶ and Hasted may be referred to, as bearing testimony to the former importance of the ports of Hythe, Romney, and Lympne.

The Saxon Chronicles, Anno Domini 893, quoted by Camden, Lambarde, and other antiquarians, show that the Danish fleet, of two hundred and fifty ships, came up the river Linnæ to Appledore, and as high as the Weald, or four miles from the mouth. Lambarde, also, refers to the decay of the ports on this coast.

The plans of Romney, Walland, Denge, and Guildford Marshes, preserved in the Cottonian Collection, throw considerable light upon the changes in this locality, showing that in Elizabeth's time, there was an inlet of the sea at Hythe, with two arms, one in a north-east and the other in a north-west direction, and a considerable accumulation of shingle to the westward of this haven, gradually diminishing to windward. The shore, in the neighbourhood of Hythe, tends naturally to promote the collection and deposit of shingle, forming, as it does, a deep bight in the east side of the bay, between Dungeness and Folkestone; the high ground, or cliff, north of the canal, between Sandgate and Hythe, assuming the form of rounded and gently-declining downs. When standing upon the hills above Hythe Church, and looking westward, it is easy to imagine, that a haven here, or at West Hythe, must have been gradually blocked up, by the deposit from the ocean, as the whole area between the sea and the Royal Military Canal, with the exception of a small belt of saltings, next the latter, exhibits parallel series of curves, running

¹ Mr. Elliott's Paper 'On the Dymchurch Wall,' published in the Min. Pro. Inst., C. E. vol. vi., p 466, gives a detailed account of this division of the coast.

² Vide Lambarde's Topographical Dictionary, 1570.

³ Vide Stukeley's 'Itinerarium Curiosum,' 1724.

⁴ Vide Campbell: Political Survey of Great Britain, 1774.

⁵ Vide Boys' History of Sandwich, 1792.

⁶ Vide Reynolds' Itinerary of Antoninus, 1799.

in a south-west direction, near West Hythe, over a waved surface of sand, shingle, and scant vegetation. Opposite Moncrief Fort, the surface to the sea-shore, a distance of about two miles, is composed of large pebbles, in undulating waves, displaying the periodical accession to the coast, very similar to the annular rings in timber; east and west of this, patches of saltings may be seen, gaining upon the beach; and at first sight it appears as though the shingle had overrun the marsh land, which, however, is not the case; but the beach is gradually brought into cultivation, by a coarse description of grass first making its appearance, then furze, or gorse, broom and moss (the resort of birds and sheep), together with seeds, &c., brought by wild fowl, and thus the surface becomes gradually clothed, bare beach and cultivated fields being intermixed: this is particularly the case at Hythe, where cultivation has been extended almost to the margin of the sea, but still bounded on each side by arid beach.

The various local deposits below Lympne and West Hythe, clearly indicate the outlet of the ancient haven. The accumulation between Hythe and Dungeness progressed up to a certain period, when, by the continued extension of, and increased accumulation at Dungeness, the natural supply from the westward was arrested, and the result has been a diminution of Hythe Beach; the portion removed and carried to the west of Folkstone, not having been latterly replaced by a corresponding supply from the westward.

In addition to the diminution of Hythe Beach, the shingle has almost entirely disappeared from the frontage of Romney Marsh, which formerly derived its sole protection from a bank of beach, and is now entirely dependent upon an artificial work for its protection. (Plate 4, Fig. 1).

A considerable decrease of land has taken place, westward of the defences to Romney Marsh; the haven of Romney Hoy becoming gradually silted up. The two spits on the east side, which, in 1847, covered 200 yards in width, were formed in twelve years by east winds, and by the constant drawing away of sand and shingle from the eastward, in front of the warren, the material being carried by the indraught into "Romney Hoy," and afterwards banked up into a permanent "full," by a return of winds from the westward: these parallel "fulls," tail round from the eastward into the Hoy, in regular curves, tending northward. On Romney Sand, which is bounded on the east, by "Little Stone End," and on the west, by "Great Stone End," (from whence to Dungeness is one continued bank of shingle,) there is not a single pebble to be found, nor is there any indication of shingle having travelled over its surface; from

which fact it is commonly inferred, that the shingle does not pass over it from the westward. The extraordinary changes, at least the more recent ones, at Dungeness, and other points, may certainly be sufficiently accounted for, by neighbouring local vicissitudes of an opposite and counterbalancing tendency; but still it is possible to conceive, that shingle might pass over this level tract of sand, in heavy weather, without leaving any perceptible trace of its progress. A wall has recently been erected on the east side of Romney haven or "hoy," to defend the low land from high tides.

On the west side of Romney, the outlet of the ancient port, formed by the outfall of the River Rother, and the various bends, points, and reaches, are still apparent, the old channel being lower than the surrounding marsh, with walls, or banks on each side.

Between New Romney and Lydd, high sandy and beach knolls are met with, assuming to the westward the shape of three parallel ridges in shore, of the same form as "fulls." Another bank, at right angles to these, runs from the west end of Lydd, towards the body of beach; and on the west side of the point, eastward of this ridge, a superior description of marsh land (Denge Marsh) is met with, probably formed by a deposit silting up eastward of this spit of shingle.

Lydd, formerly a port, is now completely surrounded by shingle, constituting that remarkable spit of land called Dungeness, which has for many years attracted great attention. Lambarde¹ refers its denomination to the Saxon "Neshe" and Latin "Nasus" a "Nebbe," or nose of projecting land; Somner terms it "Stone End"—"Lapis appositus in ultimo terræ." Collins² describes it, and Dr. Batteley, as quoted by Harris,³ considered the Lapis Tituli of Nennius was here.

The Harbour Commission of 1840, reported against it, as a site for a refuge harbour, on account of the continued increase of the spit, as indicated by the necessity for altering the position of the lighthouse, which at its re-erection in 1792 was 100 yards from the sea, and at the period of the last survey was 218 yards distant, showing an increase of 118 yards in forty-seven years. The original lighthouse, was, at the erection of its successor in 1792, 640 yards from the shore. The Commission of 1844 also reported on it, referring to its excellent anchorage, and the danger of interfering with nature in such a spot. Captain Washington, in his Report of

¹ Vide Lambarde's 'Perambulation of Kent,' 1570.

² Vide Collins' Coasting Guide, 1689-1693.

³ Vide Harris' History of Kent, 1719.

1845, shows the vast amount of deposit, by a comparison of former with recent soundings.

The changes in this remarkable formation have been so extraordinary, that the various vicissitudes it has undergone, require careful consideration.¹ The parallel "fulls" of beach, between Romney and Lydd, before described (Plate 4, Fig. 1), which may be traced from Winchelsea, on the west, to Hythe on the east, both from their appearance and from the records existing respecting the maritime origin of these places, seem formerly to have constituted the sea-coast, and supposing this to have been the case, at one period, no such point as Dungeness could have existed. The rectangular "full" running from the banks on the west side of Lydd, towards the point, may have been created by an accumulation of shingle travelling from the westward, and held in check by the outfall of the River Rother, as may still be seen in many existing harbours; the angle contained by this spit and the coast to the westward, would become gradually filled with shingle, a silty deposit would take place on the east side, consequent on the gradual loss of the harbour of Romney (whose ruin was probably complete, when its waters became diverted towards Rye), and this would form the nucleus of Dungeness, which would in time be increased in length, by the parallel ridges of shingle, periodically added to, and travelling round it; eventually another action would be evolved; for this projection, instead of offering a fair line for the shingle to travel upon, would form bays, so that the waves from the westward would meet with direct opposition in the bight of the bay, causing a decrease in this particular portion of the shore, and the shingle, thus removed to the eastward, would assist in the elongation of the point and its increase to the south east.

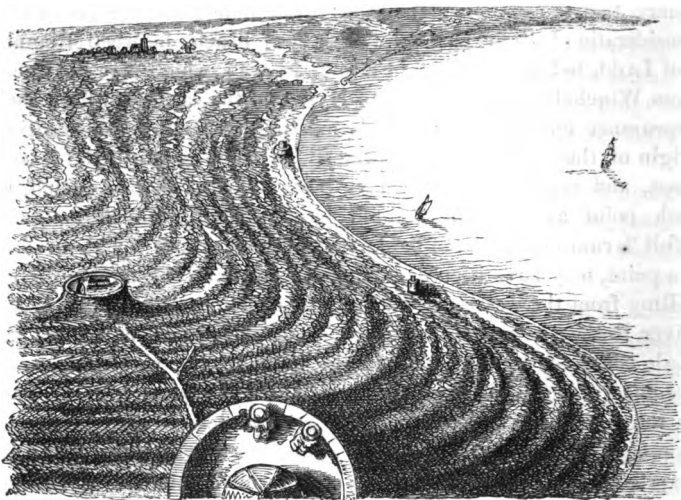
In forty, or fifty years, the decrease on the western side of the point, has been from 50 to 80 yards in breadth, or about 4 feet a year, and about thirty years ago two forts were destroyed by the encroachments of the sea.

For half a mile north of the lighthouse, patches of vegetation occur, composed of gorze, or furze, fern, broom, and masses of wild sage, and in some places, patches of moss, whilst towards Romney the shingle is comparatively bare; but around the lighthouse and towards the sea, the point of most recent formation, a light coarse thin grass grows; the last formed "fulls," however, next the sea,

¹ Vide Dugdale's "Imbanking and Draining," 1652; Segmond's Topographical History of Kent, 1782; Clarke's Tour—South of England, 1793.

are, from their recent date, entirely bare of vegetation. (Woodcut, Fig. 1.)

Fig. 1.



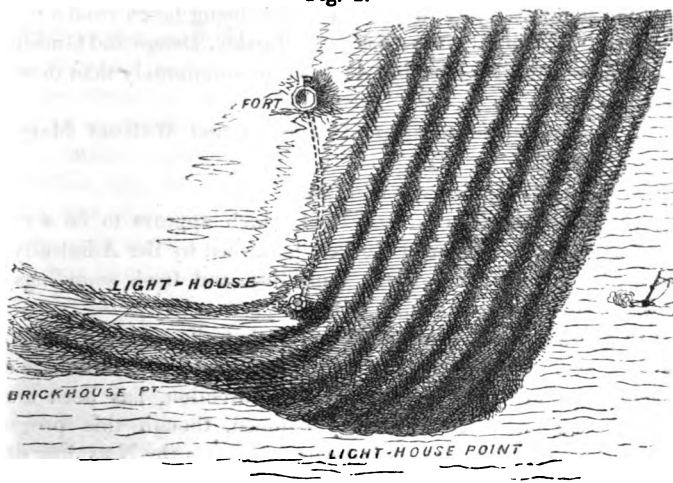
The inner ridges of shingle are nearly parallel to the coast, on the west, curving round at the point and running nearly at right angles, on the east side, towards Romney. The best idea of this formation may be obtained, by viewing it from the summit of the lighthouse tower, where the successive and periodical layers of shingle, parallel, continuous, and unbroken, may be traced for miles, marked distinctly by the wild herbage, which seeks the hollows between the "fills," tending from the N.W. towards the point, then curving round in a bold sweep to the S.E., and bending round in a counter, or concave curve towards Romney.

Of late years, from the eating away of the shore on the western side, the more recent formations commence near the lighthouse, following with a parallel margin, round the eastern side, towards Romney, and terminating at "Great Stone End," which assists to some extent, as before stated, in gradually closing up "Romney Hoy." Each successive layer of shingle commences rather to the eastward of its predecessor: the projection of "Lighthouse Point," (Woodcut, Fig. 2) which has a bold convex outline, is constantly travelling to the S.E.; west of this, and immediately south of the lighthouse, the outline of the beach is straight, or slightly concave, joining a convex outline westward.

Seven, or eight hundred vessels may sometimes be seen in this bay,

and also in the east bay, lying within two, or three miles of "Lighthouse Point."

Fig. 2.



The sea-margin was in 1847, about 200 yards outside of the lighthouse, the point being formed of six "fulls," or ridges. Beyond the Tower, to the westward of the point, the beach is flat; at the point, and round to the eastward, the upper part of the outside "full" lies at an angle of about 2 to 1; but this becomes flatter after heavy gales; the surface of the point is about 7 feet above high water: but the presence of seaweed indicates that the spray is occasionally thrown over it. At Dungeness, as elsewhere, the largest pebbles may be observed to the eastward; those at "Lighthouse Point" exceeding in size those to the westward, and increasing in size towards "Great Stone End," from which circumstance the name is no doubt derived.

The average increase of the Ness, of late years, would not appear to have been regular, as from observations taken during the last two years, it has increased to a very great extent: sometimes there must have been an increase and sometimes a diminution; but it is impossible to compare, with any degree of accuracy, their relative extent; as their bearing, from any fixed point, has never apparently been taken.

Numerous old maps of this locality, of which the most trustworthy have been selected as examples, afford an opportunity for drawing some general conclusions, respecting the more recent changes, connected with this curious formation. (Plate 4, Fig. 1.)

These authorities are—

1°. An extract from the Cottonian Collection, No. 25, of Augustus I., vol. 1, of the period of Elizabeth: it is more to be relied on, than some examples in this collection, being taken from a chart, to a large scale, of Romney, Walland, Marsley, Denge and Guildford Marshes, and the Ness being laid down more minutely than in more general plans.

2°. A very accurate map of Romney and Walland Marshes, published by Cole in 1617.

3°. The Ordnance survey of 1794.

4°. The Admiralty chart of 1844, which appears to be a transcript of a chart by Græme Spence, published by the Admiralty in 1809, with a correction of the shore line, and fresh soundings to show the shallowing around.

These examples prove conclusively, that the average progress seaward, over certain terms of years, producing a determinate aggregate elongation, in a south-easterly direction, has been much greater than has been generally assumed, though this progress has not been regular, and during certain periods the Ness has even been stationary.

During the reign of Elizabeth, the distance from Lydd Church, to the extremity of the point, was three miles; in 1617 this distance was three miles and one-eighth, which gives an annual progression of about 5 yards; in 1689, according to Collins, this distance was three miles and one quarter, which gives an absolute seaward projection of 3 yards per annum, during a period of seventy-two years; in 1794 the distance was three miles and three-quarters, giving an average annual increase of $8\frac{1}{2}$ yards, over a term of one hundred and five years, or setting aside the authority of Collins, as doubtful, the average annual rate of increase, from 1617 to 1794 will be $6\frac{1}{2}$ yards. In 1809 the distance, according to Græme Spence, was three miles and three-quarters, which yields no annual increase from 1794. In 1844 the distance was three miles and seven-eighths, which gives an annual increase of $6\frac{1}{2}$ yards from 1809, or from 1794 an annual increase of nearly $4\frac{1}{2}$ yards. Again, taking the absolute increase from 1689 to 1844, the average is 7 yards per annum, and throwing aside Collins, as doubtful, the average from 1617 (Cole) is nearly 6 yards per annum. These results show, that the average annual increase, during two centuries, has at least amounted to nearly 6 yards, and supposing all the authorities, quoted above, to be correct, this increase has fluctuated, reaching over certain periods an average of 8 yards per annum.

The supposition, that the extremity of the Ness now progresses

eastward, is confirmed by an examination of the "fulls" of shingle, composing the extreme point, showing their addition eastward, and their wasting away westward. Observations on the coast towards Rye are also confirmatory of this.

The parallelism of the cases east and west of Romney Sands, at the same time that the spits of shingle are tailing round in opposite and contrary directions, is curious, and it is only by careful surveys and repeated observations, on every portion of the neighbouring coasts, that a satisfactory explanation of the exact causes, producing their formation, can be hoped for. From an examination of Langley Point, and other formations on this coast, which are very similar to the one now under consideration, the belief is induced, that all the attendant circumstances, connected with these extensions, have not heretofore been sufficiently taken into account; but whatever opinion may be formed, as to the original source of these immense supplies of shingle, there is sufficient evidence to prove, that the coasts are constantly undergoing great and remarkable changes, and it is in reference to the intimate connection subsisting between such natural and varying agents and the stability of harbours, that this description of the south coast has been attempted.

The map by Cole in 1617 and also that of the reign of Elizabeth, show a pool marked as the "Old Haven," situated between Holme Stone and a parallel "full" to the southward: here, as at Rye, alternate strips of beach and of alluvial land, are found, which have no doubt been formed by bars of shingle, and by parallel deposits taking place under them.

Towards Rye Bay the beach is much flatter in its slope, and of less extent than at the point, there being sand for half a mile in width, from low water of spring tides; and during the last twenty years the sands have increased, and the "full" of beach has decreased, as is evidenced by the extent of the fishermen's kettle-net poles.

In walking towards Rye, patches of natural (diluvial) soil (peat), which are said to have made their appearance within the last forty years, and which from their nature may be supposed to wear quickly away, may be seen rising above the sandy foreshore, plainly denoting the recent recession of the shore line; west of the Preventive Station, called the Boundary Station, which is close to the county boundary, the clay makes its appearance above the sand of the foreshore, and the end of a sea-wall may be seen projecting through the shingle.

Reverting to the original cause of the formation of Dungeness Point, it has been assumed, with some apparent plausibility, that the meeting of the tides at this point has influenced its origin. This theory,

at least as regards Dungeness, is open to several serious objections; first, a formation of this description is very little influenced by the tides, although the base might have been so formed, and similar shingle-spits are found tailing round and across the outfalls of tidal rivers of great velocity; secondly, a similar formation, projecting from a small indentation in the coast, is found at Langley Point, where there is no such assumed meeting of the tides, and the origin of which may be traced to the former existence of a tidal harbour to the leeward of it; causes affecting also, no doubt, the formation of Dungeness. Captain Anderson, in a paper read before the Royal Society,¹ gives it as his opinion, that the tides meet at the Kentish Knock, the Goodwin Sands dividing the flood-stream, one course of which is up the Queen's Channel, and the other along the Dutch coast; the ebb-stream flowing through the King's Channel, and along the Flemish coast on the opposite side; that the meeting of the tides is in a diagonal line, from the Kentish Knock, to the entrance of the Sleeve," and that the Long Sand probably resulted from this meeting.

Major Rennell,² whose beautiful and elaborate works and charts illustrative of his particular theory, respecting oceanic currents, are so well known, agrees, to a considerable extent, with the views entertained by Captain Anderson. In one portion of his work, he refers to the Straits of Dover, as being too narrow to allow a level to be maintained; and in another part, in speaking of the general set, or current, from the Straits of Dover, at the back of the Goodwin, along the coast of Flanders, he attributes the loss of vessels at the back of the Goodwin, to an acceleration of this current during S.W. gales.

Playfair,³ in his *Illustrations of the Huttonian Theory of the Earth*, thus refers to the meeting of the tides, and the results thereby produced:

"The formation of the banks on the coast of Holland, and even of the Dogger bank itself, has been ascribed to the meeting of the tides, by which a state of tranquillity is produced in the waters, and of consequence a more copious deposition of their mud."

The results recently published by Captain Beechey, and to which the Author had access, subsequently to writing this paper, appear to indicate the neighbourhood of Dungeness as the junction.⁴

¹ Vide *Phil. Trans.*, 1819, p. 217.

² Vide Rennell 'On Currents West of Scilly,' 1815, and 'Atlantic Currents,' 1832.

³ Vide Playfair: 'Huttonian Theory of the Earth,' 1802.

⁴ Vide Captain Beechey's 'Observations on Tidal Streams,' *Phil. Trans. Roy. Soc.*, 1848 and 1851.

It is unnecessary to enter into the cause of the decrease of the entrance to Rye Harbour, which in the time of Elizabeth was a considerable estuary.¹

The absence of shingle on the east side of Rye Harbour and in the bay, of which many similar instances might be adduced, is curious, and it is inferred, that the shingle must pass across the bay, at such a depth as not to be noticed, otherwise it is impossible to conceive how Dungeness has been kept up. The vast increase of beach to the westward, may be assumed to have been produced entirely by the leeward motion.

Winchelsea Castle, now in ruins, and one mile and a quarter from the sea, and the old town, which are stated by Leland,² Holinshed,³ and others, to have been destroyed by the sea in 1250, were once adjacent to it. The whole of this area is composed of shingle, with the exception of the "Nook" creek, or "Greedy Gut," whose origin is perhaps attributable to a cessation in the supply of shingle, probably caused either by falls of the cliff, or by the pier at Hastings, which was destroyed in the reign of Elizabeth, and the removal of which would restore the circulation of shingle, permitting it, subsequently, to form in front of the sands collected during its retention to the westward. The formation of this "Nook" is sometimes attributed to the new harbour to the westward, and to its waters being diverted to the eastward by the shingle.

The "fulls" decrease in width towards Fairlight, following the indentations of the cliff, which falls much towards Hastings, where a considerable inlet existed in 1576, according to the map of England, by Lawrence Nowell, Dean of Lichfield. Lambarde calls it a "Haven Towne;" Camden⁴ says, that in Athelstan's time, it possessed a mint, and was the chief port. In 1792 a "Stade," formed by the remains of the pier destroyed in Elizabeth's reign, and the piles and masses of stone could be seen at low water; in Horsfield's⁵ Sussex, there is an account of the fruitless efforts made for its reconstruction in 1595, and in 1597 another pier, which had been erected in 1596, was destroyed. Since that time various proposals have been made for constructing a harbour at this spot. The accumulation of beach here, has been increased by groynes, which have

¹ Vide Meryon on Rye Harbour; Weale's Quarterly Papers, vol. iv. Pt. 7, No. 2, 1845.

² Vide Leland's Itinerary, 1539.

³ Vide Holinshed's Chronicles, 1577.

⁴ Vide Camden's Britannia, by Gough, 1551-1623.

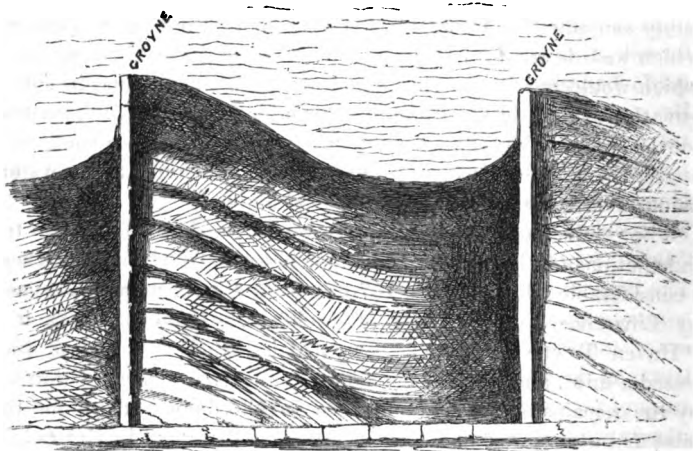
⁵ Vide Horsfield's History of Sussex, 1835.

[1851-52.]

retained the shingle, travelling from the westward, resulting partly from the falls of the cliff, at Beachy Head, and partly from the degradation of Langley Point, a source of supply that does not appear to have been generally noticed.¹

The breaks in the line of beach at Hastings and St. Leonards, caused by walls and groynes, must be prejudicial, as a natural sea margin always assumes a curved and easy-flowing line, except at the outlet of some river, and the much-quoted benefit of groynes, as a general measure of defence, appears to be, in this instance, doubtful, although they may be useful to a frontage of limited extent. The examples of these structures along this coast, are as variable in direction, as those recommended in 1849, when some persons proposed an obtuse angle to windward, or an acute one to leeward, and others exactly the reverse. (Woodcut, Fig. 3.)

Fig. 3.



They appear to cut a large bay, with gentle curves, offering but little resistance to the wave, into a multitude of lesser bays, by which a number of new antagonistic forces are brought into play; the upper "full," if large, frequently overtops the groynes, and travels on quite irrespective of them. An esplanade wall, without groynes, seems to produce the best result.

The recession, or degradation of the shore line, westward of St. Leonards, as far as Pevensey Bay, (Plate 4, Fig. 2,) where there formerly existed a haven, now entirely blocked up by shingle, has

¹ Vide Hastings Guide, 1794.

been very great (amounting, in some places, to as much as 7 feet per annum), and several Martello Towers have in consequence been removed by the Ordnance, and others will have eventually to be abandoned; the groynes along the shore being of little use, from the beach having retreated inland beyond their influence, and passing on irrespective of them. The lee side of Langley Point, where it joins the main shore line, has increased during the last century, from the degradation westward, somewhat similar to that at Dungeness. The sea, no doubt, formerly flowed up to the hills at Pevensy, over what is now marsh land; and Collins shows a considerable inlet here, without any indication of such a spit as Langley Point. The plan, by Dummer¹ in 1698 (Plate 4, Fig. 3), denotes the then condition of the haven, with the site of the ancient outlet westward, showing how the motion eastward had gradually stopped up the harbour, as at Hythe and elsewhere. Camden² refers to the castle being two miles distant from the sea, and to the want of evidence as to when the ocean forsook it, as he says there is no mention of ships, when Rufus, in 1087, besieged the castle for six weeks against Odo Bishop of Bayeux, and Robert Earl of Moreton. Jeakes, Gough, Horsfield, and other writers, refer to the former importance of this port.

The similarity between Langley Point (Plate 4, Fig. 2) and Dungeness is very remarkable. The old "fulls" of this formation run N.E. and S.W., parallel to the high land of Bourne; the modern "fulls" tailing round them, and forming the margin of the Point. The large area of old parallel "fulls" between Pevensy and Eastbourne, clothed by a scanty vegetation, the existence of pools of water, the wasting away of the west of the Point, the local accumulation on the eastern side, the shallowing of the bays, and the eating away of the coast, beyond the Point, to the eastward, are all circumstances similar in their nature to those at Dungeness. The shingle also, as at Dungeness, may be observed to increase in size, at No. 60 Tower, the eastern termination of the Point; the largest pebbles being observed on the top "full," the beach being steeper and the outline hollow opposite the fort, between Towers No. 67 and No. 68. (Woodcut, Fig 4.) The modern "fulls" of shingle, about six in number, at the Point, and to the eastward, decrease in number westward, and run parallel to the outline of the bays; but the older formations, behind the Martello Towers, have an angular direction

¹ Vide Dummer, &c. Report on Harbours, S. W. Coast, MSS., Slo. Collect. 1698.

² Vide Camden's Great Britain, 1586.

to the modern formations, and run in a more northerly and southerly direction. (Woodcut, Fig. 5.) The beach has decreased since the erection of the towers; from No. 69 westward, the number of

Fig. 4.

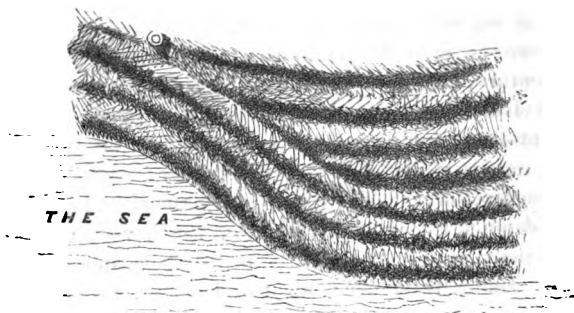
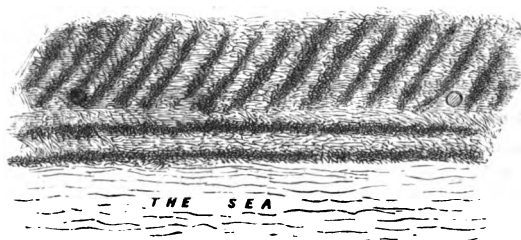


Fig. 5.



modern "fulls" gradually diminishing to one "full" in front of Tower No. 72, which abuts against the ancient "full." These "fulls" have been eaten away by the sea, and carried eastward, adding to the number in that direction. The remains of the boundary walls of a fort (which was washed down about fifty, or sixty years since), similar to that at the Point, situated between Towers No. 69 and No. 70, plainly show this decrease (which has amounted to nearly 2 feet 6 inches per annum), for in 1808 there was a breadth of 50 feet of beach in front of the outer wall.

The footings of the three last towers in Eastbourne Bay, Nos. 70, 71, and 72, are exposed, particularly those of No. 72, which is almost isolated, and has been partially protected by a groyne; and within the last five or six years the stability of this tower has been much endangered.

When the Martello Towers were erected in 1808, those numbered 70, 71, and 72, measuring from their centres, were respectively

177, 184, and 143 feet from high-water mark of spring tides ; which shows, that there must have been an average yearly decrease of the shore of about 4 feet.

At Langley Point, there is a strong confirmation of the chalk cliffs, being the source of supply of a great portion of the shingle, for it may be observed, that a large percentage of the pebbles on the west side of the point have not, as is the case further east, lost their chalky covering, or their natural form. This may be observed in other places, where the source of supply is near at hand ; whilst after travelling a greater distance these chalk nodules become pulverized. The "Sea Houses," east of Southbourne, are much exposed ; the grand redoubt on the east side of this place, and on the west side of Eastbourne Bay, is threatened with destruction ; the "full" of beach is close to the fosse, the upper portions of its walls next the sea are completely exposed ; still every precaution appears to have been taken to save this doomed structure, groynes having been erected across the area of beach in front of it, and the upper part, where the earth has been exposed, is covered with stakes ; the sea, by wearing away the shore on each side of it, has formed the ground immediately around this fort into a description of cape, or jutting point, the shingle forcing its way inland on each side of it, The most effectual way to protect this redoubt would be by constructing a pitched stone slope around the base of it.

Pevensey Bay, formed by the projection of Langley Point, as also Eastbourne Bay, on the west side of it, covered from the westward by Beachy Head, have both attracted attention, as sites for the formation of a harbour of refuge. A breakwater was recommended in Eastbourne Bay, by the Commission of 1840, it being one of the three sites selected. The Commission of 1844 recommended a site on the western side of Beachy Head.

Respecting the formation of Langley Point it may be observed, that the extraordinary vicissitudes of increase and decrease it has undergone, like those that have affected Dungeness, do not appear to have met with the attention they deserve, more particularly when the neighbouring bays are reported on as sites for the formation of national harbours of refuge.

From reference to old authors, it appears evident, that at an early period, this formation did not exist, but that the sea flowed over what is now marsh land, and washed the base of the hills on which Pevensey Castle stands. There does not appear to be any record of the commencement of the accumulation of this spit ; but in all probability its origin, like that of Dungeness, was the travelling of shingle from the westward, producing a bar, or spit of shingle, to the west-

ward, or windward of a tidal harbour (Pevensey), whose outlet alternated from west to east (Plate 4, Fig. 3); sediment being promoted to leeward (east) of this spit, a nucleus would be formed for increased accumulation. Such might have been the condition of this spit in its infancy; and the pools of water formed in the centre of it, as at Dungeness, appear to a certain extent to corroborate this view; the shingle constantly travelling from the westward, would gradually tail completely round to the eastward, and perhaps, as may be seen in many other instances, such as Dover, Yarmouth, &c., would eventually pen up, or landlock the upland waters; the accumulated drainage waters, seeking to discharge themselves, would force a passage through that portion of the beach offering the least section of resistance, which would be to the eastward; the point also still increasing in that direction, the outlet of Pevensey Haven would thus continue to progress to leeward. This view is borne out by the survey and plans of 1698, at about which period the landowners appear to have taken steps to render the drainage permanent, without reference to the capabilities of the waters, as a haven, and the stream ultimately became a sewer, with a sluice through the shingle.

The plan by Lawrence Nowell, Dean of Lichfield, A.D. 1576, does not show any such projection as Langley Point; but it may be observed, that neither is the projection of Beachy Head clearly defined; it is therefore doubtful whether this map can be relied on, in the present inquiry; but the plan by Collins, in which Beachy Head is clearly defined, and the haven of Pevensey to the eastward of it, with a considerable entrance and two arms, or branches, contains no notice of such a projection as Langley Point. (Plate 4, Fig. 2.) Connected with the absence of this point, in old maps, it may also be stated, that Camden omits any mention of it.

The extent of the point is clearly laid down in a well-engraved map, from an actual survey of the county of Sussex, with admeasurements of the sea-coast, &c., by Richard Budgen, A.D. 1724. It is also clearly defined in a beautifully-executed MS. map in the possession of the Honourable Board of Ordnance, by Desmaretz and Foucquet, in about 1736; being a survey of the coast of Sussex and Kent from Chichester to Rye, and from Rye to Ramsgate, together with enlarged surveys of the various harbours and forts. Desmaretz' map is considered at the Ordnance as a very accurate authority. The topographical survey of Sussex, by Yeakell, or Jeakell, and Gardener, in 1778, which is a well-executed map, to a scale of two inches to the mile, approximates closely to the above authorities.

From these data the increase of the point, up to a certain period,

is clearly shown, when it extended one mile and a quarter into the sea, in a S.E. direction. Supposing there to have been no such accumulation, when Nowell's plan was made in 1576, the result would be, over a space of two centuries, of an average annual seaward progression at the extreme point of 10·89 yards. Supposing the deposit to have commenced subsequent to the time of Collins, the rate of increase would be more than double the above. These results are however very doubtful as measurements.

This accumulation having obtained a certain progression seaward, and the western supply being cut off, by old Brighton Beach failing to furnish it, or other causes, elements of a destructive character would then come into play, and in this respect results similar to those at Dungeness, but much more extensive in their nature, are perceived.

From the Admiralty Survey of 1844, it appears that the projection of the point was then seven-eighths of a mile from the road leading to the "Sea Houses" at Bourne; in 1724 this distance was one mile and three-eighths; in 1736, according to Desmaretz, it was one mile and a-half; in 1778, according to Yeakell and Gardner, it was one mile and a-quarter. Taking these dates, the following results are obtained:—From 1724 to the present time an annual average recession of 7·33 yards; from 1736, 10 yards; and from 1778, 10 yards. This is by comparing the high-water lines; if the low-water marks are taken, a greater result will be obtained, as the slope of the point was formerly much flatter.

The waste of this point, during more than a century, must have formed no inconsiderable source of supply for formations to the eastward, and the alluvial matter therein contained must have assisted in the shoaling of the bays. It will be observed, that as the point has been eaten away, and the beach been driven round to the eastward, the slope has been rendered steeper; this decrease has given the point an apparent N.E. progression. A small amount of accumulation has taken place on the east side, filling up the hollow there.

It will be seen, by referring to Plate 4, Fig. 2, that the eastern end of the breakwater, proposed in 1840, in four fathoms water, at low-water spring tides, touches the low-water line of 1736.

It is necessary here to observe, as a remarkable coincidence, that from Dungeness to Langley Point, there is (except at the mouths of harbours) an uninterrupted belt of shingle. During the last century there has been an elongation of the eastern point at Dungeness, which appears to have eaten up the superabundance of the supply from the westward, over the same period. There is a corresponding

diminution of the western point (Langley), which appears, by its decrease, to have afforded the requisite eastern supply. The intermediate belt, though subject to various fluctuations, does not appear, on the aggregate, to have altered much as to quantity generally; but on the whole to have been driven more landward. This coincidence is curious, and, coupled with other circumstances, leads to the conclusion, that upon a certain line of coast, the decrease at one spot is balanced by a corresponding increase at another locality.

Another curious feature respecting Langley Point is, that the period of the commencement of its accumulation appears to coincide, very closely, with the destruction of the ancient fortified town of Brighton, built upon the beach below the cliff, where is now situated the chain pier; this would afford the requisite western supply of shingle.

It is worthy of notice, that no such assumption as the meeting of the tides can be broached in reference to this spit, but that the two formations of Langley and Dungeness have been produced under cover, as it were, or more properly speaking to leeward of Beachy Head, in reference to the prevailing S.W. winds and the flood tide; a particular eddy, or rotary motion of which, might have been entailed by the configuration of the channel, and a sandy, or silty deposit formed, as the basis of these shingle-spits; that both have had tidal harbours to leeward of them; that while the western spit was on the increase the eastern one was stationary; but that whilst the western formation was on the decline, that on the eastern side increased in an almost corresponding ratio.

SECOND SECTION.

FROM BEACHY HEAD TO PORTLAND.

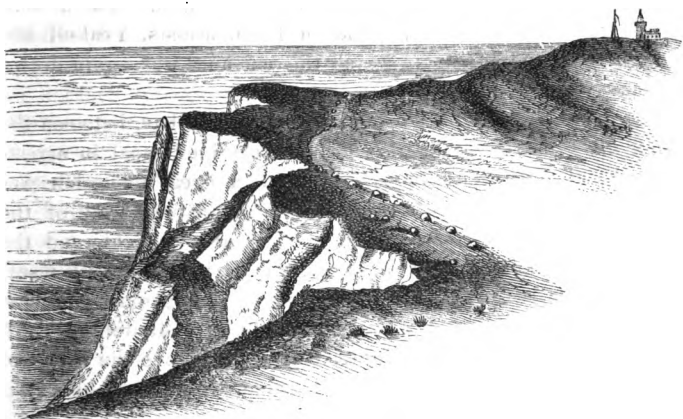
The degradation of the cliffs, at Bourne, is very great, notwithstanding the artificial defences. Under Beachy Head, the small belt of shingle at times entirely disappears, local falls of this cliff occasionally arresting the beach; and an instance of the durability of chalk, when drained, is afforded by a remarkable pinnacle,¹ called the "Charleys," which has stood for more than a century; formerly there were three of these pinnacles. (Woodcut, Fig. 6.)

The River Cuckmere which has, at present, an uncertain outlet through the shingle between the heads of Beachy and Seaford, must have suffered great change, for Camden describes it as being a very

¹ This pinnacle has since fallen, 1853.—Sec. Inst. C. E.

considerable harbour, and Collins as a "Bar Haven," with 6 feet at low water, and from 13 feet to 14 feet at high water. The "full" of beach travelling across this bay, more extensive than is to be seen either on the east, or the west, almost closes up the out-

Fig. 6.



fall of the river, which with difficulty preserves a shifting and uncertain outlet to the eastward, under the cliffs, a large portion of the penned-up waters escaping, by filtration, through the beach, which at the back spreads over the saltings. A spit extends from the main "full," round the west and south sides of the Channel, which is thus projected seaward in a south-easterly course, undermining the cliffs in that direction; and a remarkable horn is formed, at the back of the commencement of this spit, apparently by the eddies caused by the reflux of the penned-up waters: the main channel can be easily crossed at low water, as it is then divided into several small streams.

The high downs at Seaford Head are 360 feet above the sea, descending rapidly to the Vale, wherein Seaford is situated; the position of which is very similar to Cuckmere, and it was formerly the outlet of Newhaven Harbour.¹ A lofty and extensive "full," of beach, bounds this flat recession in the coast, behind which, on the east side, the last Martello tower, No. 74, and a fort and battery, are situated. (Plate 4, Fig. 4.)

The Government Report, of 1698, attributes the decayed condition of Newhaven, to the collection of beach and, "inning out," of

¹ Vide Fortune on Newhaven, 1825; Mantell's Geology of Sussex, 1827; Ditto, S. E. of England; 1833; Ditto, Wonders of Geology, 1839.

the tidal waters : the plan shows the ancient outlet, near the present entrance, blocked up by shingle, and the effluent waters driven eastward, towards Seaford, encumbered by shoals, and in its conditions very similar to Shoreham at an early period; the works that had been ineffectually constructed, to direct the waters, are also shown. There is also a curious plan of the harbour, in "Yarranton's England by Sea and Land;" and in 1778, Messrs. Yeakell and Gardner published a map in which the entrance was again drawn to the westward.

There are a large number of groynes along the bay, between the harbour and Seaford Road, but they are very ineffectual in arresting the beach. In the summer of 1850, a great explosion was undertaken at Seaford, to stop the constant wasting away of the cliff; this however could only be of temporary benefit, and the greater part of the debris has been already carried away by the sea. West of the harbour, under Barrow Head, a long groyne has been erected, which has created a moderate "full." Mantell^a gives a section of this cliff, showing the tertiary strata above the chalk, of which Lyell says, the existence may become a matter of historical record, from the constant degradation of the cliff.

Towards Rottingdean every step brings to light some indication of the constant decay going on, now fissures and rents near the edge of these high cliffs, and now old tracks of the preventive men intersecting them, new tracks being formed further back : on the east side of Kemp Town, the cliff has fallen much, as shown by the repeated diversions of the road. Numerous groynes have been erected to arrest this decay, and an immense projection of shingle, formed by the groynes, juts out below this place, completely altering the natural shore line. The cliff in front of Brighton is rendered more permanent by a wall of concrete, and by groynes at the foot. Westward of the Chain Pier, where the cliff dies away, and where the esplanade forms a projecting point, several large groynes hold a considerable quantity of shingle in check, the difference in the level of the windward and the leeward sides at times exceeding 10 feet. There are two general "fulls" along the whole frontage which, when uninterrupted by groynes, preserve a good line; towards Shoreham there is a large accumulation, bounding the bay, and forming the southern barrier to the harbour. In the Cottonian Collection there is a very curious map of Brighton and the surrounding country, representing the descent of the French under Admiral

¹ Vide Yarranton's 'England's Improvements by Sea and Land, 1677.

² Vide Mantell's 'Geology of Sussex,' 1822-27.

Claude d'Armebaut, dated July 1545, which shows, that Brighton then extended much more to the southward. Camden says, that it was strongly fortified in Elizabeth's time, but that the works were undermined by the sea, and in the Addition to Camden, by Gough in 1806, the town is referred to as being "now greatly reduced by the encroachments of the sea." In Lee's *Ancient and Modern History of Lewes and Brighthelmstone*,¹ it is stated, that many houses were destroyed, in a storm on the 27th November 1703; and another dreadful storm occurred on the 12th August 1705, which "completed the destruction of all the lower buildings which had escaped the fury of former inundations."

Further, in 1713, he says—

"The sea, which had destroyed everything below the cliff, now encroached with alarming rapidity on the cliff itself, fragments of which daily crumbled into the sapping tide. It was therefore found absolutely necessary for the protection of the rest of the town, to erect groins before it."

He minutely describes the construction and effect of these "groins," and appears to think, that the term is of Saxon origin, signifying an accumulation of sand, or beach.

Manteli, likewise, dwells at length on the destruction of the town; and Lyell² in mentioning the great decrease of the coast of Sussex, considers the sea at Brighton to have resumed its ancient position, and that the old town was situated upon a beach, which had been abandoned for ages by the sea.

The fluctuating character of Shoreham Harbour (Plate 4, Fig. 5) prior to the erection of Mr. Chapman's piers was well known. Camden refers to the destruction of a great part of the lower town by the sea, also to the decadence of the port, from the accumulation of sand and shingle, and says that vessels, in former ages, could come up to Bramber, under sail. The shifting character of the outlet is described by Collins, Lambarde, Gough, &c. &c., and the Government Report of 1698, before alluded to, describes its uncertain nature.³

The plan, accompanying this Report, shows what a wretched condition this port must have been in, at that period, and how much it has subsequently been improved; the fluctuating character of the

¹ Vide Lee's *Lewes and Brighton*, A.D. 1795.

² Vide Lyell's *Geology*, A.D. 1840.

³ Vide Gough's *British Topography*, 1780; *Additions to Camden*, 1806; *Young's Agriculture*, County of Sussex, 1808; *Dallaway's History of the Western Division of the County of Sussex*, 1815.

outlet is also evident, from the then existing entrance pointing directly south, and a previous one, called the "Late Outlett," pointing south-west.

The various surveys of this locality, published at different periods, show the variations in the entrance, and the encroachment of the sea on the shore, notwithstanding the local accumulation of shingle; similar effects have already been noticed to the eastward, and will also be observed to the westward.

Horsfield refers to the former importance of Shoreham, to the landing of King John there, and to the fitting out of two fleets amounting together to seven hundred and six vessels, in 1346, during the reign of Edward III. : at that time it was called upon to furnish the navy with as many vessels as Plymouth, and more than were demanded from Newcastle, Bristol, or London; that in the following century, its success, which for three centuries after the Conquest appears to have been uninterrupted, received a check; and in 1432 a petition to Parliament from the burgesses, craving a reduction of assessment, stated that—

"Forasmuch as by the encroachment of the sea and other causes which have reduced the number of inhabitants to thirty-six, they are unable to pay their assessment of twelve shillings," &c. &c.¹

Westward of Shoreham, the coast has been considerably abraded, especially near to Lancing, involving the erection of a sea-wall to protect the high-road, which received some damage in 1837: the removal of the Preventive Station further inland, and the serrated low clay shore thence to Worthing, with "fulls" driven close up against it, are also indicative of this waste. The numerous groynes along the frontage of Worthing attest how severely the waste has been felt there; many of these may be seen ruined and buried by the great increase in the sandy foreshore, and to the westward a large projecting bank of shingle has been formed by the modern groynes. The sea gains much on the low coast thence to Littlehampton, where there is but little shingle.

The Harbour Reports of 1698, the works of Martin,² and other sources of information, shew the great changes that have taken place in the River Arun, from alluvial deposits, and winning of lands. The tortuous outlet of this river, the manner in which the shingle tailed across it, and the way in which it was encumbered by shoals, before the introduction of piers, is well shown upon the plan by

¹ Vide Chapman's Report on Shoreham Harbour, 1815-1822, and 1823; Vazie, ditto, 1816; Clegam's Sailing Directions to ditto, 1823.

² Vide Martin's 'Geological Memoir' (West Sussex), 1828.

Dummer, which accompanies the Report of 1698. (Plate 4, Fig. 6.) The ruins of a portion of Cuttleworth church, then situated at the edge of the cliff, show very clearly the condition of the shore at that time. The state of this haven is still very inferior, as the outlet is dry at low water.

The sea gains rapidly on each side of the harbour, notwithstanding the groynes running out along the frontage of the town; not many years since large fields existed on the west side of Littlehampton, where now there are "fulls" of beach. The destruction of Middleton church, notwithstanding groynes and defences, the existence of fields in front of the Preventive Station east of Bognor, now nearly surrounded by water, and protected by groynes, and the state of the groynes and shore, along the frontage of Bognor, are all evidence of this wasting away of the shore, of which Middleton Ledge and Bognor Rocks were no doubt formerly the boundaries. Mantell refers to the latter, to the Barn Rocks between Selsey and Bognor, the Houndgate and Street Rocks, on the west, and Mixon on the south of Selsey, as the only records of the sandstone strata forming the sea-coast line.

The manner in which the shingle has deserted the groynes along this coast, shows plainly the gradual encroachment of the sea: west of Bognor the "fulls" of beach become very irregular; the shore is much undermined, as far as Pagham Harbour, where fields existed in the memory of persons now living, over which the waters of the entrance at present run. Mantell refers to the great encroachments on this coast, as evidenced by historical records; Horsfield says that Pagham Harbour was caused by a sudden irruption of the sea in the beginning of the 14th century, at which time, according to the Nonæ Roll, (1345,) 2700 acres were devastated. Of late years the harbour has been much silted up, and in consequence of the variable nature of the channel, only small vessels ever attempt to enter. On the east the land is low, and on the west there are high "fulls" of shingle, similar in appearance to those at Dungeness and Langley Point, caused by the indraught and by winds from the eastward; these "fulls" terminate in a spit, enclosing the harbour entrance on the west and south, then tailing round in bold curves, in a northerly direction, at nearly right angles, to the general line of beach, and gradually advancing eastward, the land in that direction decreasing in a corresponding ratio; the extent to which this movement is going on, may be gathered from the fact, that eleven, or twelve years ago the entrance was 200 yards to the westward. The removal of the Bishop's see from Selsea to Chichester proves, that the great wasting away of this part of the coast commenced at an early period, and the

anchorage of the "Park" is supposed originally to have formed that portion of the Bishop's domain, from whence it derives its name. According to Captain White,¹ in his *Sailing Directions*, a gravel bottom here "thinly covers a strong clay," showing, that either the velocity of the tide through the western channels has swept shingle over the clay to the eastward, in a depth of water of from 3 to 5 fathoms at low water, or that it has been drawn away from the shore, by the waves produced by particular winds, the result in either case being similar to what has been observed in several places to the eastward: and in this particular instance being undoubtedly due to the tidal currents between Selsea Bill and the Mixon. That the bank off Selsea Bill, called the "Boulders," is composed of shingle, may be plainly seen, at low water, in fine weather: but this does not prove, whether the shingle travels near the shore, or whether the formation is alluvial, or diluvial, as the oldest surveys have laid it down.

At Chichester Harbour there is a similar action to that at Pagham, the shore to the eastward suffering loss, and to the westward a spit of sand and shingle being formed, which tails inwards and diverts the outfall, digging a channel for itself through the clay, in which logs of timber are frequently found. The shore westward, to Langston Harbour, the entrance to which is surrounded by sandbanks, is of much the same character. Along the shore of Portsea Island there is a belt of shingle, which has somewhat decreased near the Castle.

The entrance to Portsmouth Harbour, which has preserved its character for several centuries, is an exceedingly instructive example, exhibiting a deep entrance channel, between two natural spits, forming a bell-shaped inlet, through a shingle shore. The numerous artificial works in this locality have been erected principally as shore defences, and the channel has been effectually covered from south-west winds, so injurious to other harbours along this coast to the eastward, by the Isle of Wight. The position of Portsmouth Harbour, does not admit of any comparisons being drawn between it and other harbours on the south coast, for the conditions of this harbour are so nicely balanced, and the shingle so limited in amount, that though affording ample protection to the shore of the outlet, it is not in such quantities as to allow of its being carried away. The formation of Kicker Point, an elongation of shingle to windward of a tidal harbour, is very similar, though on a smaller scale, to those at Dungeness and Langley, and it has arisen doubtless from nearly

¹ Vide White's 'Sailing Directions for the English Channel,' 1846.

similar causes; but the result has been modified in this instance, by the greater power of the backwater. Near the entrance of the harbour, the point has tailed round, so as to form a tidal basin, and the natural result of any extension of this point will be, the ultimate enclosure of a pool of water, or mere. Such broads, or meres, exist, in many places, in connection with similar spits, but in some instances they are produced entirely by landwater. The entrance to Portsmouth Harbour, under such a view was, no doubt, in former ages much wider. The form and depth of the harbour itself, however, according to old surveys, as far back as the reign of Henry VIII., do not appear to have varied much, and it may be cited as a remarkable instance of a deep tidal harbour, through such a fluctuating medium as shingle.

The principal points relating to the entrance to Southampton water, which presents analogous features to those before described, are the state of Calshot Point on the west, which, according to Leland's description, does not appear to be much altered, the Brambles on the east, and the Thorn bank in the centre. The spit on the east, called the Brambles, has been produced, apparently by an eddy, caused by the confluence of the Southampton water and the sea, on the north side. The spit called Calshot Point, on which Calshot Castle, built by Henry VIII., with its accompanying dwelling-houses, &c., and a stone glacis to defend the point, are situated, consists of a bank of shingle, one mile in length, tailing out like other similar formations, on the west side of the entrance, and terminating in a natural horn, which forms a tidal estuary, called Ower's Lake.

The outfalls of Beaulieu and the rivers westward, present precisely similar appearances, only on a modified scale. Between Beaulieu, Lymington,¹ and Hurst, there is a very large marine deposit of fine pebbles; as evidenced by the ditches, saltworks, &c., a manufacture which has been established here for at least three centuries, the reservoirs covering the low shore and, where abandoned, forming coarse saltings. The low-water channel of Lymington winds over a large area of silty deposit, formed under the lee of Hurst Point, which stands out from the coast as a natural groynes; so effectually arresting the progress of shingle from the westward, that it only makes its appearance again, in any quantity, to the eastward of Lymington Creek.²

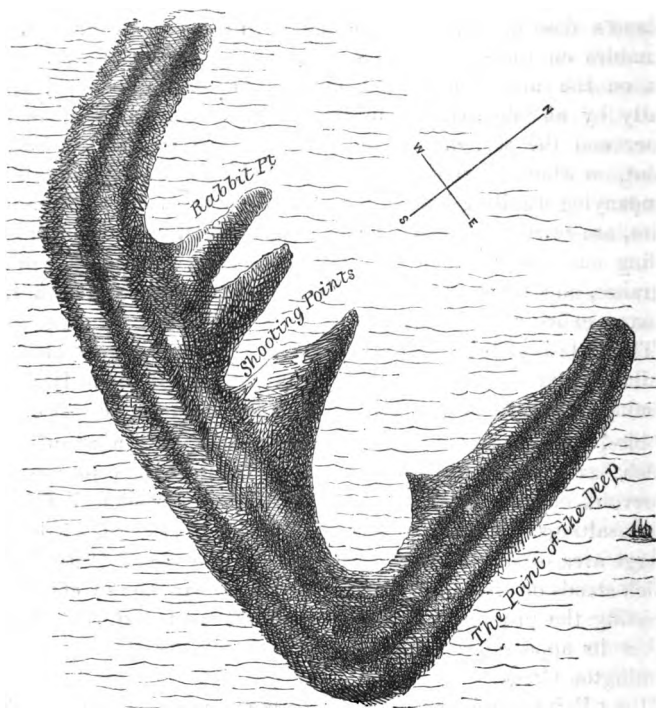
Hurst Point, running out in a north-west and south-east direction, is a straight, natural mole of shingle, two miles in length, composed

¹ Vide Warner's Tour round Lymington, 1789.

² Vide Warner's Collections for a History of Hampshire, 1789-94.

of rounded chalk flints on an argillaceous base, terminating in a nearly perpendicular submarine cliff, 200 feet in height: it has afforded shelter, and acted as a breakwater, to the different small tidal harbours between it and Southampton, but has materially affected their capacity as to depth, by producing a large silty deposit. Warner, in his topographical remarks on the south-west coast of Hampshire,¹ refers to this fact. Camden and others describe the castle built at the extremity of Hurst Point by Henry VIII., to the singularity of the position of which Webster refers in Englefield's Isle of Wight.² Lyell also particularly describes this singular barrier, the materials of which, he thinks, have been supplied from the waste of Hordwell and the neighbouring cliffs to the westward, and he further refers to a great alteration of its position in the storm of November 1824. (Woodcut, Fig 7.) The Author, however,

Fig. 7.



¹ Vide Warner's Collections for a History of Hampshire, 1789.

² Vide Webster on Geology of Isle of Wight; Englefield's Isle of Wight, 1816.

believes, from an examination of ancient maps in the Cottonian and Burleigh Collection, and many of subsequent dates, in all of which its peculiar hornlike termination, due apparently to the indraught to the north-east, is shown, that this spit has preserved its general outline for many centuries, though it may have been subject to local variations. Within half a mile of the lighthouses, the beach curves more to the eastward, and from one irregular "full," forks off into three, or four steps, or gradations, resembling the "fulls" of other similar formations, and denoting the modern variations and additions at the extremity, locally termed the "Point of the Deep," which is one quarter of a mile in length, and nearly at right angles to the main mole of shingle. Two smaller rectangular spits tail out in a similar manner, and would appear to denote the projection of the point in former ages, or they may have been caused by the receding of the waves within the main beach.

Across the entrance to the Solent, there is a bank of shingle, stretching from the ledge, called the "Bridge," off the Needles, to near the extremity of Hurst Point.¹

Many of the characteristics of Hurst Point are also peculiar to the Chesil Bank, Calshot Point, and other similar formations; such as a low flat shore to leeward (eastward), and a highly-inclined beach seaward, with a tendency to curve round to the northward and eastward, and eventually to enclose a tidal mere, or estuary. The elevation and size of the pebbles increase towards the extremity of the point, and in places, on the sea slope, an intermixture of coarse sand and shingle, which has become solid and homogeneous by age, crops out through the modern beach. The cliffs westward of Hurst Point, rise gradually in height, and are composed of clay below, and sand and gravel above, much serrated and water-worn, cause the frequent occurrence of slips in the upper strata. The percolation of drainage water, the debris from which form a small undercliff below, and in the neighbourhood of Hordle huge masses of fallen cliff alternate with hollow chines. It appears, from local evidence, that previous to June 1849, 8 yards in width of the cliff, at Barton, had been gradually washed away, in the same number of years, and during the concluding eighteen months of that period, the ratio had been increasing: similar observations would apply to the whole frontage of Christchurch Bay, from Hurst to the mouth of the Avon.

The shingle, immediately to the west of Hurst, as is universally the case to the windward of these spits, becomes smaller, and not greater in quantity than might be supplied by the cliff itself. Further west,

¹ Vide Warner's History of the Isle of Wight, 1795.

[1851-52.]

there is generally a clean shore of sand between high and low water, but with particular winds shingle accumulates, until it is swept away again by another wind. The shingle along this shore is more angular and solid in bed, than that on the coasts of Kent and Sussex, and where the sea has cut into the beach the appearance is very similar to that of the cliff above.

The effects of this waste are indicated by the artificial protection of rough piling and stones, along the low shore east of Christchurch Harbour.

The outfall of the rivers Avon and Stour, which is more north and south than it was eight years since, forming Christchurch Harbour, is landlocked by Hengistbury Head, and the east and west spits of shingle forming the mouth, so that at high water it becomes a large tidal estuary, the bar at the entrance being nearly dry at low ebbs, and never having more than 7 feet of water over it. The remains of Lord Clarendon's old stone pier, locally christened the "Long Rocks," built in the reign of Charles II., and described by Yarranton, may be seen at low water, and though being partially buried in sand, only about 200 yards in length are visible, it in reality extends half a mile beyond low water, running out across the fore-shore, in a south-east direction. (Plate 4, Fig. 7.) The state of the harbour in 1698, with its choked outlet, and the piers at that time constructing, in continuation of the works commenced by Lord Clarendon, are well shown in the plan by Dummer. In 1837 Mr. James Walker proposed an outlet near the same spot.

The spit of sand which forms the south boundary of Christchurch Harbour has a curved shingle belt upon it, mixed with coarse sand on the sea-side, marking the range of the tide, and above, on the inner side, wind-driven white sand "dunes," which becoming more regular in form towards the point, average a height of 20 feet to 30 feet, compose the main body of this natural barrier, and in a recess, north of the head, the shingle assumes three distinct "fulls." Hengistbury, or Christchurch Head, formed by the outcrop of the tertiary strata, is very subject to slips, and this tendency is increased by the quarrying of ironstone, which occurs in broken seams, 3 feet to 4 feet in thickness at the base of the cliff.¹ On the west side of the

¹ The degradation of the cliffs at Harwich, from a similar cause to that at Christchurch, and the consequent advance of Landguard Point, on the opposite side of the harbour, which has, for the last fifty years, been at the rate of twelve yards per annum, are graphically described in a Report by Captain Washington, R.N., in the Appendix to the Second Report of the Tidal Harbour Commission, 1845, p. 208.—*Sec. Inst. C. E.*

"REPORT

head, off which there is deep water, there is a considerable "full" of large, round, water-worn pebbles, once much used in the neigh-

"REPORT OF CAPTAIN WASHINGTON on the Memorial of the Mayor and Corporation of the Borough of Harwich.

"Woolwich, January 19, 1843.

"The port of Harwich, owing to its general depth of water, its extent, the shelter it affords, and immediate communication with the sea, is one of the most valuable on our eastern shores; and although the rivers Thames and Humber afford shelter by running far up them, yet Harwich, from its easy access by night or by day, in all weathers, and in all states of the tide, is the only harbour of refuge, properly so called, on the east coast of England.

"The memorial of the mayor and other inhabitants of the borough of Harwich states, that in this harbour, which, in easterly gales, has given shelter to five hundred sail of shipping at once, great changes have taken place within the last twenty years, owing to the falling down and washing away of Beacon Cliff, on the western side of the entrance, and the growing out of Landguard Point on the eastern side, whereby the harbour is already much deteriorated, and is daily becoming worse.

"To the truth of this statement I can bear the fullest testimony from my own observations during the last two years, and all the evidence I can obtain goes to show that the sole and immediate cause of the damage in question, is the digging up and carrying away the cement-stone from the foot of Beacon Cliff and Felixstow Ledge.

"From the unanimous testimony of the older inhabitants of Harwich, it appears that Beacon Cliff (which is entirely composed of blue, or London clay, with layers of Septaria, or cement-stone) has fallen away much more rapidly within the last twenty-five years than it did at any previous time; but not feeling quite satisfied with this evidence, I have procured plans of the town and cliff for the years 1709, 1756, and 1804, and have transferred the high and low-water lines for these several periods to the plan of Harwich, completed last year in Her Majesty's ship 'Shearwater.' From which it appears, that in the first half century less than 40 feet, or not a foot a-year, of the cliff was washed away; in the second half century about 80 feet went to sea; while during the last thirty-seven years the sea has advanced in a direct line upon the land not less than 350 feet; and the beach at the foot of the cliff has been so much lowered, that the low-water line, during this short period, has gained 600 feet upon the shore, thus presenting on the western side a greater surface of water, whereby the scouring effect of the flood and ebb streams in keeping the channel clear is much weakened—a barrier that tended to shoot the ebb tide over against Landguard Point is removed, full forty acres of ordnance, glebe, and manor lands, of excellent pasturage, with tenements and other property, have been swept away, and the harbour deprived of an invaluable breakwater in southerly and south-westerly gales.

"Now the traffic in cement-stone began about the year 1812, or thirty years ago, since which period I am credibly informed that upward of a million of tons of this stone have been carried away from the shores in question. This fact, combined with the evidence derived from the plans, seems conclusive as to the cause of the encroachments of the sea upon Beacon Cliff. "But

bourhood for paving; the foreshore consists of sand, with ridges of pebbles, the larger and upper one formed of two "fulls," lying against the base of the head, and marking the range of springs; and the lower, or smaller one, of a shingle "full," marking that of neaps. At one period there was a larger quantity of shingle under Hengistbury Head, when little sand was to be seen; this diminution is partly to be attributed to the excavating of ironstone from the shore around the head, which commenced six years back.

About a mile west of the station, on the top of Hengistbury Head, and opposite to Wick, the cliff gradually dips down until the upper stratum of gravel meets the shore, and a small cliff is formed of "dunes," or hillocks of sand, cast up by the sea, attaining, in some cases, an elevation of 60 feet, and forming a breastwork to the pasture lands of Christchurch Vale. Further on, the cliffs, against which the sand drifts, increase in height, and towards Bournemouth they attain considerable altitude, their summits being crowned by a wild range of sand-drifted "dunes," about a furlong in width, constantly varying in form, and giving an original character to the coast.

The "dunes," although rendered, for a time, apparently permanent, by the growth of vegetation, appear to recede, and to gain upon the neighbouring fir plantations, as the cliff below is wasted by falls arising from the land drainage. At Boxcombe, east of Bournemouth, the cliff attains an altitude of about 200 feet; and here the crowning sand hillocks, covered with patches of heath, terminate.

"But while the sea has gained upon the land on the western side of the harbour, the contrary has taken place on the eastern, or Suffolk side, where, within the last thirty years, Landguard Point has grown out 1,500 feet, thereby blocking up the chief entrance into the harbour, so that where, in the year 1804, was a channel 7 fathoms deep at low water, is now a shingle beach as many feet above high-water mark.

"This mischief has been accelerated by carrying away the cement-stone from the foot of Felixstow Cliff, about two miles and a half to the north-eastward, where it formed a rocky projecting ledge, which served as a breakwater, for the whole of this shore, from the force of the sea in north-easterly gales. But since this stone has been removed (to an extent of 200,000 tons I am told), a large slice from Felixstow Cliff has gone into the sea, two martello towers and a small battery, only built in 1808, have been swept away, and the beach at Landguard Point has grown out, as above stated, to the extent of 500 yards, in consequence of which the two lighthouses, erected but a few years since, at a great expense, are no longer a safe leading-mark into the harbour; on the contrary, they have already caused serious damage to several vessels by running them ashore.

"These are great and increasing evils, and demand immediate attention if the port of Harwich is to be preserved."

The Chine, at this place, exhibits the great power of water, the gravel and yellow sand being worn into rocky-shaped masses, the white sand below assuming the most fantastic shapes, and the clay at the base taking a rocky outline. East of the Preventive Station, situated on the west side of the Chine, called "Bateman's" road, about one mile east of Poole Harbour, the frontage of cliff is only 30 feet in width, where, within the memory of persons living, there was a space of about 200 feet. A fall, which occurred about four years back, now forms the undercliff.

Poole and Wareham Harbours,¹ formed by a large, land-locked, tidal estuary, are enclosed seaward by two natural moles, or sandy spits, jutting out from the high land on each side, the cliff on the north-east side sloping suddenly down to the spit, which is evidently of marine origin, and increases regularly in width towards its extremity, which consists of fine, white drifted sand, with three large hillocks of considerable elevation (the highest called "High Horse Manger"), covered with rough tufts of gorse and heath.

The sands on the western side of the harbour are blown across to the eastern side: a point, lying off the entrance on the west side, is called "Drift Point," and the bar is called the "Hook."

The Basin of Poole was no doubt at one period a main, or direct inlet, from the ocean. The plans by Dummer in 1698, Mackenzie in 1785, and as corrected by Lieut. Sparke in 1829, exhibit its relative conditions, and a new survey has recently been made of the harbour by the Admiralty. Whitworth also surveyed and reported on this harbour in 1787, and Mr. Rendel in 1827, and again in 1831.

The great width of the entrance of this harbour, and the protection afforded by the high land to the westward, present very considerable advantages in addition to the double tide, which is also peculiar in a modified degree to Christchurch.

On the west side of the entrance, a shoal runs into the harbour towards Brownsea Island, at right angles to South Haven Point. A level sandy foreshore, 450 yards in breadth, dipping suddenly to the sea, extends southward beyond the line of "dunes."

Around the curve of the bay, in which there are a few rocks, the cliffs are generally low, sloping, and grass-grown, intersected by several chines, or valleys, leading up to Studland; large boulders form a beach on the sandy shore, marking the tide range. On the south side of the bay the cliffs become lofty, Studland Down rising to the great elevation of 430 feet, and cropping out in a chalky pro-

¹ Vide Coker's Survey of Dorsetshire, 1732.

montory, called promiscuously Foreland, Handfast Point, and Old Harry Head, at the base of which the flint boulders are probably larger than on any other part of the coast. To the north of this head there is a large accumulation of beach mixed with chalk, forming a solid concreted mass, overgrown with vegetation. During east winds the sand below is sometimes washed away, and exposes a larger quantity of shingle than is usually apparent. The chalk cliffs increase to the westward, and the flints in them are much larger in size than those of Kent and Sussex.

The downs of Handfast Point slope suddenly, and crop out into lofty cliffs seawards, which are cut up into various small indentations, or bays, in which there are local "fulls" of shingle; off this point there is a singular cluster of isolated chalk peaks, somewhat similar to the Needles, called "Old Harry and his Wife."

The south-west side of this promontory descends suddenly to Swanage Bay, succeeded westward by the tertiary clay and sand cliffs, as in the other bays eastward, a finely-curved shingle beach, with a large percentage of chalk pebbles, showing how local is the supply forming the sea-margin to this beautiful bay. The cliffs gradually decline towards Swanage, with numerous slips and intervening chines, where the shingle stops and is succeeded by a sandy shore; inducing the supposition that this local beach derives its supply from Handfast Point, the bay being entirely protected from the southward and westward by Peverel Point, a rocky promontory, which forms the southern boundary of Swanage Bay. The top of this point is rounded and grass-grown, the stone cropping out on the shore; and two large ledges of rock running out into the sea in a south-easterly direction, creating a race, which appears to extend a mile out, and small overfalls of tide near the shore.

The iron-bound and bold shore of Durlleston Bay is formed by the recession between Peverel Point and Durlleston Head, a black frowning promontory, which rises gradually out of the sea in deep water, capped with downs above: at the base there are large broken detached masses of oolitic rock, mixed with boulders.

"Tilly Wym" Quarry, which supplied the stone for Old London Bridge, but has not been worked for the last fifty or sixty years, is situated at this point. Thence to St. Albans Head, the race of which is caused apparently by the outset from the bay, combined with the rocky and broken ground, there are precipitous stone cliffs, with rapidly-ascending downs, rising to the height of many hundred feet. An undercliff runs round "Chapman's Pool," its bold shore being strewn with detached masses of stone and small patches of shingle formed of Purbeck boulders. The promontory, called

"Hounds' Stout," or "Round Stout," or "Snout," forming the west boundary of "Chapman's Pool," rises to the height of 500 feet, or 600 feet, with a rough undercliff below, and the shore strewn with fragments of stone. The shore bordering the two next points, which are of little elevation, has small indentations, or bays, free from rocks, with clean margins of fine pebbles and sand. The cliffs west of Encombe are formed of hard indurated blue clay, locally called "wark," dipping eastward, and underlying the Purbeck stone. Those at Kimmeridge rise to a height of 150 feet, or 200 feet, presenting alternately seams of stone and clay, which dip eastward, and crop out on the foreshore in extensive reefs, called "Kimmeridge Ledge," running out into long projecting points covered with sea-weed, and forming steps of irregularly disintegrated slabs, which are eventually split up by the wind, weather, and sea into detached masses, and worn into pebbles and boulders. Westward the cliffs increase in height, and the chalk again making its appearance, siliceous pebbles are found on the shore.

The eastern boundary of War Cove, which is the western end of the Purbeck strata, is formed by a singular mass of stone, of a conical shape, called "Warbarrow Tout," having rugged, precipitous, and nearly perpendicular sides, the south-western extremity terminating in lofty sharp rocks. East of this the rapid dip of the Purbeck strata and the outcrop, seaward, in a series of rugged headlands, are beautifully displayed.

The beach along War Cove is of small, rounded siliceous pebbles, mixed with Purbeck boulders and ironstone from the tertiary cliffs above, in four regular and well-defined "fulls," the largest pebbles being on the top, and the smallest to the westward, as has been observed elsewhere.

On the west side of the bay this beach is bounded, near high-water mark, by immense blocks of chalk, fallen from the high cliffs above, which at their eastern outcrop are rugged and nearly perpendicular; the continuation of the beach is of rounded flint and chalk nodules.

The stratification of the west headland of this bay is very curious. The flint veins, which next the sea are nearly perpendicular, gradually take the curve of the valley, showing that the chalk was originally deposited in this form. Large detached masses of 10 tons to 30 tons in weight, lie at the base of this cliff, and in the summer of 1849 a still larger mass fell.

Lulworth shore, further west, is strewn with huge masses of fallen chalk, but there is little shingle, except in the deep indentations and water-worn caves in the base of the cliff, into which it is driven

at high water. Mewps Bay, the next in succession, is formed by a chalk reef, called "Black Rock," running a considerable distance into the sea, in which the strata is vertical, and terminates in sharp needle-like points. The shore of this bay is formed by a fine shingle beach, and with smooth chalky reefs on the foreshore below. "Mewps" Point is formed of highly-inclined Purbeck strata, corresponding with the east point of "Warbarrow" Bay, with a large area of reefs below, just covered at high water, and several curious isolated pinnacles.

The outcrop of the cliff westward forms Eastover Point, the eastern headland of that remarkable indentation Lulworth Cove. The stratification of the Western Point is highly inclined, dipping north; and on each side of the narrow entrance the rocks crop out in sharp shelving reefs. The beach round the cove is coarsest at the top, or north side. A large slip in the chalk cliff, at the centre of the bay, took place about 1847; and west of this, in 1849, there was an immense "full," composed of chalk pebbles. The chalk cliffs westward are very varied in outline, now forming small bays, and now headlands, cropping out seaward, with a small beach of sand, flints, and chalk pebbles. The intervening tertiary cliffs are succeeded by the oolitic promontory "Durdle Door" Point and by "Batt's Head" of chalk, intersecting the beach "fulls," and dividing them into two distinct bays.

Westward are irregular chalk cliffs and undulating downs, with three deep bottoms, terminated by a bluff jutting promontory, from 500 feet to 700 feet in height, locally christened "White Nose," which arrests the beach, and forms it into a local bay.

The chalk cliff, with an undercliff and beach below, then rapidly descends, succeeded by a low tertiary cliff, called the "Burning Cliff," against which siliceous pebbles in parallel "fulls," are arrested and held in check by the projection of "Long Nose."

At Osmington there is a tolerable collection of beach, formed by the leeward accumulation from Weymouth Bay, which is intersected at Ratcliff, or Redcliff Head.

The degradation of the shore line, on the north-east side of Weymouth Bay, has been very great. The coast road was, it is said, in George the Third's time, and long afterwards, situated at what is now low-water mark, when the troops used to encamp in a field to the north-east, now covered with sea-beach; there was also a green, outside the "Ice-house," at Melcombe Regis, when that structure was built. In front of the low marsh land, east of Melcombe Regis, where the beach does not appear to be protected by the Isle of

Portland, it travels landward, and gains upon the shore, as is shown by the diversion of the Dorchester road, for the protection of which a high retaining wall has been erected.

The shingle "fulls" gradually decrease in extent westward, in front of the walls of the town esplanade, and up to the north pier of the harbour mouth.

A comparison of the maps of Weymouth Bay and Portland, in the Cottonian Collection, with those by Collins, in 1682-9, and by Lilly in 1715, and others of more recent date, shows that in Elizabeth's time, there was a large accumulation called the "Shelf," jutting out in a triangular form, on the north side of the harbour outlet; that in Collins's time the sea had eaten into the north portion of this beach; and that the neck of land, called the "Narrow," connecting the north side of "Melcombe Regis" with the main, had much diminished in width; all which appearances are still more fully developed in modern plans.

The "Mixon," a low tertiary point, with a flat sandy shore, and a little beach marking high water, runs out from the "Nose," the headland east of Weymouth, and forms the base of the south pier of that harbour. The cliffs in the neighbourhood of the old castle built by Henry VIII. appear to have fallen much; and west of the reefs running out from this point there is a sandy bay, with two small undulating cliffs of tertiary strata and grass-grown slopes, and hillocks of drifted sand towards the Fleet, the ridge on the east side of the entrance to which (now crossed by a timber bridge on the site of the old ferry) is traversed by the road to Portland. This inner ridge has a beach of flint pebbles, Portland stone, &c., beyond high-water mark, and a long, flat, sandy foreshore: it forms the neck of land at the end of the Fleet, extending to Portland Roads.

The extraordinary mole of shingle, called "Chesil-Bank," has attracted the attention of topographical writers from an early period. Gough considered that its name was derived from a Saxon word, meaning gravel, and calls it "a prodigious heap of pebbles thrown up by the sea, beginning at Chesilton, in Portland, and reaching beyond Swyre, sixteen miles and three-quarters." He further says, "A strong north-east wind cleaves it asunder, and sweeps away all the stones, leaving only the base of black clay. A south-west wind throws up the pebbles again, and binds the whole as firmly as before. At Chesilton the beach is very high, and the stones of the size of an egg, or bigger, diminishing to that of a pea at Swyre."

Leland, who minutely described its position, applies the word "*chesil*," as a generic term to all shingle banks; and he also explains the dispersive effects of south-east winds, and the accumulative

results produced by north-west winds, which he says "Socor, strength and augmentith it."

Camden and Hutchins¹ likewise refer to this fact, and the latter to the Saxon origin of the word "chesil," calling the bank also "steepstone,"

Shaw,² in his "Tour to the West of England," made in 1788, gives the following graphic description of the bank :

"To contemplate this wonderful wall, washed up by the sea, you should ride, or walk along its summit, where you will see, more fully, the extent and security of this immovable bulwark, whose materials are mostly equal in size to a walnut, at the water side, gradually diminishing to common gravel, and though uncemented, are capable of resisting the most outrageous storms, and of preserving the adjacent country from a destructive inundation."

Succeeding authors appear almost to borrow the language of their predecessors.

Norie ascribes the dispersion to south-east winds, and the accumulation to those from the south-west.

Lyell refers to the elevation of the "fundamental rocks" forming the base, and states that the origin of the bank may have been a shoal, or reef, arresting the progress of shingle from the westward ; and many of these authors speculate upon the probability, that Portland was formerly an island, subsequently connected to the mainland by the increase of this beach.

Perhaps the most extraordinary feature in this formation is the top "full," which is about 15 feet above the lower ones, and forms a huge wall seaward, exceeding anything of the kind, both as regards bulk and height, to be seen along this coast. The land slope is flat, and the beach forms a gentle curve at the island, which it joins at Chesilton, running along its shore for a short distance, and very soon lost to the southward ; to the north-west, for a long distance, it takes a straight course. There is here a strong confirmation of what has been elsewhere observed, that the largest pebbles travel furthest to leeward, and also attain the greatest altitude.

In 1715 the height, according to Lilly,³ was 30 feet ; now the average height at the eastern end is from 30 feet to 40 feet above high water of spring tides, the crest gradually lowering to the westward, and the stones decreasing in size, the proportion of siliceous

¹ Vide Hutchins' Dorset, 1774.

² Vide Shaw's 'Tour,' &c. 1789.

³ Vide Reports on S.W. Dockyards, MSS., by Col. Christian Lilly, H. M. 'Ingenier,' 1715.

pebbles increasing. A quarter of a century ago, Fleet was 'inundated by the ocean, from a breach in the protecting mole, when the church was washed down, and many houses in Chesilton, built on the east end of the beach, were destroyed. The land-locked tidal lake, called the Fleet, enclosed between the Chesil bank and the mainland, is another peculiar feature of this locality. The undulating hills to the north-east increase in height to the westward, until they join the chalk downs, which crop out to the eastward of Weymouth, at Long Nose. The Fleet terminates opposite the valley from Abbotsbury, down which there runs a small mill stream, at the junction of the chalk and tertiary formations.

Opposite St. Catherine's, a conical hill on which there is a singular chapel, the beach is of much the same height and section as at Fleet, though the pebbles are generally finer, descending rapidly to the westward, and tailing out in spits at the back of the bank, overrunning the land, past Lord Ilchester's Castle, which is on the slope of the hill, after which the ground rises gradually, until it becomes nearly level with the crest of the beach. Between the Castle and Abbotsbury Station the great beach ceases, the bight terminating in a projection of low tertiary cliffs, which intercept the top "full;" the lower "fulls" continue of an average height, as at Deal and elsewhere, the pebbles being of every variety of material, smaller in size, and evidently the product of the cliffs westward. Two, or three miles west of Abbotsbury, the beach "fulls" are thrown up into very sharp slopes, which, from the fineness of the material, become very solid; the beach still continuing to decrease in size and altitude westward, intercepted by the cliffs at Burton, and again formed into a moderate "full" on each side of Bridport Harbour. The extraordinary elevation attained by the Chesil bank, due in a great measure to its peculiar position, shows that a greater allowance than usual must be made for the accumulation of such water-driven material; in the generality of cases these banks seldom attain a greater altitude than from 6 feet to 10 feet above high water.

The general result appears to be, that with north-west winds the beach accumulates, with those from the south-west it decreases in quantity, and with south-south-west winds, right on, the slope is increased, by the drawing down of the material. Here the dispersive forces are arrested, and held in check, by the Island of Portland, so that the former action preponderates.

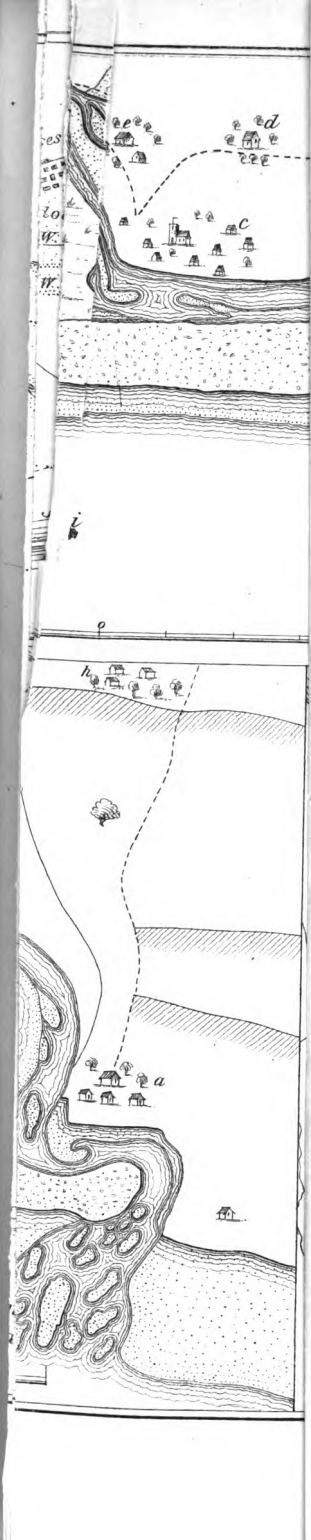
The entire line of coast, from the Thames to Portland, exhibits such extraordinary local changes, frequently of a counterbalancing character, that the bare enumeration of the most prominent features cannot fail to excite the interest of Civil Engineers, and the chief

object of the paper being to induce discussion at the meetings, and more minute local investigation by others, it is hoped, that it will draw forth valuable opinions and communications on a question which has so important an influence on many engineering works.

The paper is illustrated by a series of large diagrams of the localities described, and by sections of various beaches, from which Plate 4 and the Woodcuts Figs. 1 to 7 have been taken.

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Mr. REDMAN, in answer to questions by Mr. Walker, explained, that the authorities he had consulted, for the present state of the outline of the coast, were the Admiralty charts, and the Ordnance and other modern maps of acknowledged accuracy, and as far as was practicable, he had verified the topographical correctness of those documents, by personal inspection, having walked over, and carefully examined the whole length of coast described, for the purpose of preparing the paper submitted to the Institution. He had already given in the paper, the ancient authorities, and he had spared no expense, or trouble in obtaining access to the earliest maps and the works of the best topographical writers, as the subject was of vast importance in marine engineering, especially in reference to the construction of harbours and coast-works of defence; and he submitted, it was most desirable, that such natural agencies, as had been described, and the instances of the compensating effects of alternating loss and gain, should be correctly understood.

Mr. NEWTON directed attention to the recently-exposed remains of the Roman castrum, at Lymne: it might be presumed, that at one period, that building had been situated on the shore; and that the high lands at the back, being filled with springs, not drained away by any agricultural operations, had caused an extensive landslip, whereby the castle walls were carried bodily forward for some distance, altering the line of the coast and occasioning a deposit from the river, which probably debouched near it.¹ It was worth investigation, whether the first accumulation at Dungeness, might not have been originally formed by a somewhat similar occurrence.

Sir WILLIAM CUBITT, said, that at Rye he had counted twenty distinct 'fulls' of shingle; he apprehended that these 'fulls' coincided with, or at least were influenced, to some extent, by the lunar cycles. He would throw out the suggestion for the consideration of those who had more leisure for observations of that kind than he had, as the question was one of great interest, both theoretically and practically. He was of opinion, that Winchelsea Castle was originally built close to the sea, as the 'fulls' now extended from the Castle to the present high-water mark.

Sir CHARLES LYELL had derived much practical information from the interesting paper just read; particularly from the portions treating of Hurst Point and the Chesil Bank, to which he had devoted some attention. The effect of recent storms, on these parts

¹ Vide Smith and Elliott's Report on Excavations at Lymne. 8vo, London, 1852.

of the coast, had been commented on, in his writings,¹ which he was gratified to find had attracted the notice of Civil Engineers, whose labours were generally allied to geological studies. The features of the coast were continually undergoing changes, from the combined effects of the action of waves and of land-floods, and he had ascertained, that in the great storm of November 1824, the bank of shingle at Hurst Castle was moved bodily forwards a distance of 40 yards to the north-east; so that certain timber piles, which marked the boundary of two manors, were found, after the storm, on the opposite, or western side of the bank.

He admitted the apparent paradox of the largest pebbles, at the Chesil Bank, being found to the leeward, or farthest from the source whence they were derived; as he took it for granted that they did come from the westward: as, however, it was admitted that the velocity of the current increased to the southward, the greatest force would be exerted on the shingle in the more open channel, or farthest from the land, and in that case it would follow, that the largest pebbles would, during storms, be directed against the south-eastern extremity of the bank, or at its point of junction with Portland. The subject was so replete with interest, that he hoped some careful observations would be made by the engineers connected with the large works now in course of execution for the breakwater; and that the results would be laid before the Institution.

Mr. REDMAN stated his impression to be, that the same causes were in operation at the Chesil Bank, as at Dungeness; Mr. H. R. Palmer, in his valuable paper "On the Movement of Shingle,"² had noticed the fact of the largest pebbles being usually found at the greatest distance, with reference to the forces acting upon them; and now Sir C. Lyell's explanation to a certain extent accorded with the views entertained by Mr. Redman, who had, however, in his paper, only referred to the accelerated motion of the larger masses, and this would be found to accord with the hypothesis of the greater force exercised by the current to the southward.

Mr. RENNIE thought Mr. Redman's paper was a very valuable contribution, and would be serviceable to engineers, not only on account of the clear observations, relative to places of great interest, but for the numerous references to ancient and modern authors, affording information on the progressive states of those parts of the coast. Captain Beechey's Survey³ contained statements

¹ Vide Lyell's Principles of Geology. New edition. 1853.

² Vide Phil. Trans. Royal Soc., 1834.

³ Vide ib., 1848 and 1851.

relative to the times and places of the confluence of the tides in the Channel, which would throw considerable light on the formation of Dungeness Point, Romney Marsh and other parts of the coast, whose features were continually undergoing change, from the deposition of shingle. These opinions were worthy of careful attention, as it was evident, that at the locality of the comparatively still water, caused by the confluence of tides, or currents, there must be a deposit, which would continue to augment, until it became of sufficient extent and consistence to deflect the tide, or current, and thus to transfer the action to another spot. It was probable, that Romney Marsh had been so formed, and there were indications of the heights, along the Military Canal, having originally formed the sea-coast. Thus the ancient harbours of Rye, Winchelsea, and others, had been lost, in spite of all the attempts of Smeaton and other eminent engineers, to save them. At Hastings, all endeavours to form a harbour had proved abortive. At Newhaven, the port was preserved with difficulty, and there was reason to doubt whether the recent blasting of the cliff would be permanently useful. At Shoreham, the harbour was, in a great degree, kept open by the scour from the back-water of the internal lake up the valley.

The harbour at Poole had hitherto been a question of considerable difficulty in an engineering point of view, from the existing currents and the prevailing winds.

The Chesil Bank presented a very instructive lesson, after the great storm on the 24th November, 1824. The profile of that natural breakwater underwent considerable changes, at that time, though in a short period the usual features were again observed, showing that the causes of the accretion were not changed. That storm was so violent that it made a clear breach, destroyed some houses on the land side, and left a vessel high and dry on the top of the bank: even at that time the same disposition of the material was observed, the largest pebbles being at the top and to leeward. Mr. Rennie could not accord with Mr. Palmer's views, as to the waves acting with greater force on the top of the beach, than below.

The subject would repay the careful investigation of engineers, and he would recommend to their attention the *Treatise by Lamblardie on the Coast of Normandy*,¹ in which much useful information would be found, on the motion and deposit of sand and of

¹ Vide *Mémoire sur les côtes de la haute Normandie*; par M. de Lamblardie. 4to. Havre. 1789.

shingle, and if similar observations were made on the coasts of England, much that now appeared obscure would be explained.

Captain Sir E. BELCHER, R.N., said his experience induced him to believe, that shingle was never deposited, in any quantity, where the tide beat directly upon the shore. He was of opinion, that the largest pebbles were gradually worked up to the top of the beach, at high water, in rough weather, but in general they were rather left by the ebb, than carried up by the flowing tide. This was the case at Portland, where the ebb tide was much the strongest. He had observed, that pebbles were rarely found at the dead low-water line; the greater power, being exerted above that part, had carried them upwards.

He had met with shingle banks out of sight of land, and on one occasion had his vessel on one of these banks for two hours; it was evident they were formed by the deposit of the still water, caused by an eddy in the tide.

In answer to a question from the President, Sir E. Belcher said he believed the waves, during heavy gales, exercised power at very great depths, he had seen evidence of it in water fourteen fathoms deep. He thought the tide current did not affect depths of more than 12 or 14 feet.

Captain O'BRIEN believed, that the movement of shingle was almost entirely due to the action of wind waves, and not to the run of the tide. It rarely happened that waves set directly on the shore, but running diagonally up the beach, the pebbles were raised, or loosened by the inflow, to be clawed off by the 'undertow,' or retreating wave.

He had much pleasure in bearing testimony to the value of Mr. Redman's paper, as regarded the portion of the coast between Dover and Hastings, including Romney Marsh; a district, with which he necessarily became acquainted, as officer in joint charge of the military canal and the adjacent defences, extending from Shorncliff to the foot of Fairlight, within two, or three miles of Hastings, though he was not altogether prepared to agree in the view taken of the formation of the Marsh.

There could be no doubt, that the Rother river, which now came down through the flat country, under Wiltersham, close under the hill upon which the town of Rye was situated, and entered the sea about two miles to the southward of that town, at one period flowed through the heart of the Marsh, to New Romney. But it seemed previously to have held its course much farther to the eastward, under the foot of the side hills, and debouched within two miles of Hythe, under the walls of Lyme Castle, where there had existed

a port, known as the 'Portus Lemanis' of the Romans,¹ whence the name of that portion of the river was derived. The present insignificant stream conveyed a very inadequate idea of what the river Rother had been. From the extent of country it drained, and the accessions from the side hills, the floods during winter must have been considerable, and they necessarily washed down a quantity of silt, or alluvial soil, which tended to fill up the port; whilst the run of the shingle, on the shore, in due time, barring the outlet, completed the operation. The river then headed more to the southward; and emptied itself at New Romney, where Nature repeated the same operation, and thus it might be assumed that some portion of the Marsh was formed.²

Only a comparatively small portion of the Marsh could, however, be thus accounted for. Neither could the residue be ascribed entirely to a shingle deposit. It might rather be assumed, that a great part of the country, seaward from Appledore, was like what East

¹ Vide Stukely, *Itinerarium Curiosum*, edit. 1776, p. 131. "A little way from Hythe, at the end of the Stone street, and at a proper distance from Canterbury, is the Port of Lemanis. As soon as I came to Limpe Church, looking from the brow of the hill to the subjacent marshes, I descried the battered Roman walls, situate on the southern decline, almost at the bottom.

"This was the garrison of the Turnacinsian bands. The walls include about twelve acres of land, in form somewhat squarish, without any ditch. Here are several circular, or rather elliptic butments, as thick as the walls, and solid; the circuit is manifest on three sides, but the south wall is levelled to the ground; probably the Danes, or Saxons thus dismantled it, to render it useless against their incursions.

"Whether the sea reached the lower wall, even in the time of the Romans, I cannot determine, for I do not believe this was the port, but the castle, belonging to it. The port was somewhere to the eastward about West Hythe; this port is now called Shipway, where the warden of the Cinque Ports was anciently sworn, and where their courts were kept. Leland says the people of Limpe had a mace, the remaining ensign of their authority."—*Sec. Inst. C. E.*

² In a Memoir on the Physics of the Mississippi River, by Professor C. G. Forshey, New Orleans, U. S., 1850, it is stated, "We have shown the rate of fall, depth, breadth, velocity, and rise and fall of the water (in the Mississippi). From these we may compute the rate of discharge at all stages, and the mean for thirty years. The quantity, by these data, is 12,250,000,000,000 cubic feet per annum, or 447,199 cubic feet per second.

"It is worthy of special observation, that the mean, for the three sets of ten years, shows a lower level of discharge at each consecutive ten.

"The experiments of Professor J. L. Riddell show the sedimentary matter, transported by the Mississippi, to bear a proportion, in bulk, to the whole quantity discharged, of 1 in 3,000. At this rate the cubic contents would be, by measurement, equal to 4,083,333,333 cubic feet. The sediment, then, would cover twelve miles square, one foot deep."—*Sec. Inst. C. E.*

[1851-52.]

Anglia generally was said to have been, in the time of the Hephtharchy,—shoal water, lagoons, and morasses with peat bog. Peat was now frequently found below the surface in the valleys. The soil inland, immediately beneath the shingle in the Marsh, was a tenacious greyish clay. Between Dungeness and Hythe the clay became bluish, and was mixed with sand and shells.

Immediately in front of Hythe the soil was a greyish clay, inclining to blue, mixed with sand and shells. The clay at Shorn-cliff sluice was quite blue, without sand and shells, and very tenacious.

At the formation of the military canal in 1804–5–6, a great number of yew and oak trees, from 12 feet to 30 feet long, and from 12 inches to 24 inches diameter, were found between Wareham and Appledore, all lying prostrate, generally from east to west, and from 4 feet to 10 feet beneath the surface. They were very sound, being preserved in the peat.

The coast between Dymchurch and Romney, extending half a mile inland from the high-water mark, and called the Warren, consisted of a multitude of sand-hills, of a slight elevation, covered with ‘bent,’ rushes and orchideous plants.

Similar sand-hills were found at the western extremity of the Marsh, about Camber, where it is necessary to encourage the growth of the ‘bent’ grass, to prevent the encroachment of the sand in that direction. These sand-hills were precisely similar to those on the Dutch and Belgian coast, and on the shore between Boulogne and Dieppe, only neither so elevated nor so extensive.

These sand-hills were very destructive, unless constant attention was devoted to keeping them within due limits. The worst scene of desolation it had been Captain O’Brien’s lot to witness, was caused mainly by neglecting their advance. It was on the coast of Sligo, during the most fatal period of the famine, in Ireland, where he was sent on a tour of inspection. He there saw a tract of land, at one time protected by ‘bent,’ and very fertile, which had become an absolute sandy waste, solely through neglect of the ‘bent.’ There being nothing to impede the progress of the fine sandy particles, readily dried by the sun, and then whirled along by every breeze, the land became covered to a depth of several feet, even to the tops of the cabins, where the poor people still dragged on a miserable existence, in the very extremity of starvation, all signs of cultivation being, of course, utterly obliterated.

On the French coast, besides the ‘bent,’ ‘buckthorn’ was extensively planted, and was found to be very effective in checking the progress of the sand.

The elongation of Dungeness Point was very remarkable, and was not overrated at eight yards annually; "the sea had certainly receded upwards of half a mile in front of the lighthouse, within the memory of living men."

The old castle of Lymne was a spot of considerable antiquarian interest: an old brother-officer, resident in the neighbourhood, had, in reply to questions submitted to him, supplied some curious information, from which he would make a selection, and refer to the researches of Messrs. Roach Smith and J. Elliot, which furnished some very interesting features.¹

"The walls of Lymne Castle were chiefly composed of rag and lime stone between layers of Roman brick and tiles, both red and whitish, varying in thickness from half an inch to 3 inches, in three rows; the intervals of stone, between the brick courses, were about 4 feet, and the walls from 12 feet to 18 feet thick, composed of concrete in the centre, and quite as hard as the outer casing. There were several round towers, or rather bastions, solid and projecting from the walls, or curtains, at 70 yards, or 80 yards apart.

"The walls, on the west side, extended nearly to an ancient farmhouse (called Steedfall House), about 20 yards on the north side of the back drain. To the east of the farmhouse (parallel with the canal) there were no walls for about 150 yards, when a bluff point, evidently artificial, suddenly rose; this was opened to a depth of about 8 feet, when a mass of solid masonry appeared, and proved to be the foundation of a very large tower, or bastion, at the eastern extremity of which the walls turned northwards for about 250 yards, and then again north-west, for about 150 yards. A large tower there formed the utmost extent to the north, and then turned to the south-west, where it united with the wall leading from the farmhouse about 200 yards, thus forming an irregular pentagon.

"It would appear, that the land-springs were the principal cause of the destruction of the castle. The hill being so very steep, averaging an angle of 40° at least, particularly towards the north, and the land being, as at the present time, full of springs, so as to keep the ground always wet, even in summer. Still there was evidence that some very violent convulsive, or upheaving action must have taken place, at some remote period, as from the position in which the walls had fallen it was scarcely possible that a land-slip could have been the sole cause of the devastation: great portions

¹ Vide Smith and Elliot's Report on Excavations at Lymne, 8vo, London, 1852.

had fallen inwards, with the bases uppermost; and the principal entrance (at the east side), uncovered early in 1850, showed the base, or foundation of the gateway, torn up when the walls fell, like the roots of a tree, and the large stones, many of them upwards of 4 feet long, and 3 feet by 2 feet, appeared as steps, although they were well clamped with iron, and filled in with lead, showing the violence of the disruption of the very foundations in that part."

Mr. ROACH SMITH stated, in a communication to the SECRETARY, that from an examination he had made, with Mr. James Elliot, he was convinced, that in the time of the Romans, there had existed a great extent of dry land, all along what was now covered by the sea, and was bounded by the present Dymchurch wall, and that the country around had been somewhat thickly populated.

Mr. J. SCOTT RUSSELL said, that starting with a fixed proposition, of a given velocity of a body of water raising a given magnitude of wave, he must undoubtedly attribute the greatest moving power to the greatest depth of water, because the largest and most powerful waves would thus be created, and before they broke they would exercise the greatest amount of mechanical power to lift and convey the shingle. Thus, although the tides did aid to a limited extent, the waves must be considered as the principal agents in the effects produced.

Waves were of two classes: those due directly to the action of the wind, and those resulting from, or the consequence of that action, producing a ground swell, the latter ceasing to be under the influence of the wind, before they arrived at the place where their final effect was exhibited. These two kinds of waves produced very opposite effects on pebble beaches; the heaviest waves being created in deep water, and the lightest in the shallow water of a shelving beach; and if the velocity of the water in a wave was as the square root of its depth, and the speed of advance, of a wave of 16 feet in depth, was assumed to be about twenty miles an hour, there was no difficulty in accounting for the displacement and carrying forwards of the largest pebbles during storms; the power then developed being sufficient to deal with the largest masses, on the simple proposition of a given speed, or power, being capable of lifting pebbles of a given size, and weight.

It was not difficult to show, how waves, having the character of a ground swell, would act in the formation of pebble beaches generally, but more particularly in forming a projecting bank of shingle like that at Dungeness. There was not any evidence as to the original form of that point, but as existing charts showed that a certain contour had been uniformly preserved, during the period of

its advance, it might be fairly assumed, that a point, probably less salient, had always existed, but with a haven both on the east and the west sides of it; the general face of the coast being shelving, as was now seen above water, and the point itself much steeper than the faces of the sides. Now upon a configuration, such as had been assumed, the action of heavy deep waves, formed out at sea, would be, that on approaching the point, the groundswell waves, so constituted, would run up the east and west channels, or havens, curling as they were affected by the form and depth of the bottom, and depositing the shingle on the bank as their velocity and power were expended; and as one part of the wave would advance faster than the other, the form of the deposit was accounted for, as was that of the more vertical form of the point, by assuming the more direct action of the wind-wave upon it, and that heavy pebbles, brought on by the more powerful wave, would be disturbed and would roll down into the two channels, to be carried forward diagonally by the swell.

The same course of reasoning would, he conceived, account for the filling-up of Hurst and Calshot Points, and other similar formations, as well as, under the modified circumstances of locality, in solving the question of the deposit of the Chesil Bank.

Captain Sir E. BELCHER admired the ingenuity of Mr. Scott Russell's views, but he doubted their soundness, as unfortunately those parts which according to his theory should be the most shelving, were in reality the steepest.

Mr. S. B. HOWLETT, through the SECRETARY, directed attention to Key Haven, opposite Yarmouth, Isle of Wight. When the sun was low in the horizon, the whole surface of the projecting peninsula enclosing the haven, appeared to be covered with parallel longitudinal stripes, or ridges, running nearly north and south, each marking the accumulation of shingle resulting from some stormy tide, and demonstrating that the peninsula had been formed by successive layers of shingle travelling from the east, in the Solent. About thirty years ago there was a timber stage projecting into the Solent, at right angles with the spit; but the increase of the beach had been so great, that now only the heads of two, or three piles were visible. Whilst this accumulation was taking place on the east face of the spit, the south extremity was liable to severe casualty, and could only be permanently retained by the construction of a breakwater, which would eventually be required.

Mr. JOSHUA WILSON, through the SECRETARY, after alluding to a communication (signed 'Observer') published in the "Nautical

Magazine ;”¹ stated his conviction, that waves possessed sufficient power to move shingle at considerable depths : inasmuch as though, at Sunderland, no vessels were permitted to throw ballast overboard at a less depth than 5 fathoms, yet great quantities of flint pebbles were found on the beach, which could only have been derived from that source, as they were not met with ‘in situ,’ in any cliffs within the range of the seas bearing on Sunderland.

He was inclined to attribute the formation of such points as Lowestoftness and Dungeness, in a great measure, to the transporting power of the waves being weakened by the shelter of banks of sand, or that of the opposite coast.

It might be expected, that in localities where accumulations were in progress, the largest shingle would be found heaped at the highest points, because it was deposited by the on-shore gales, which by raising the surface of the waters in-shore, produced an off-shore current, which scoured away the sand in a seaward direction, and under circumstances more favourable for its development, such as a greater inclination of the shore, with augmented strength in the gale, would convey with it the small and even medium-sized shingle. Sometimes this action, on a shore, which became flatter towards the low-water mark, formed an evident bar, derived from the steeper portions, and to which it was restored on the return of fine weather.

At Sunderland, for local reasons, shingle could only be accumulated by artificial means, as the power of the preponderating northerly gales on that coast, was so great as to sweep everything along the shore, unless groynes were constructed to arrest the progress and to cause a deposit.

Mr. J. WRIGHT, through the SECRETARY, directed attention to the present artificial accumulation of shingle at Brighton, where there had previously been a constant degradation of the coast, even to the extent of the destruction of part of the old town. The cliff, on which the eastern part of Brighton was built, was composed of a sort of marl, locally called Coomb Rock, overlying the chalk, but separated from it by a stratum of gravel of about 3 feet in thickness. As this gravel was just about the level of high-water, it was easily washed out by the waves, and contributed materially to the falling of the cliff, which being of less consistence than chalk, yielded more readily to the action of the percolating surface water. These causes, combined with the absence of shingle, in front of the cliff, induced such repeated falls, that the safety of the

¹ Vide “Nautical Magazine,” January, 1846.

houses, between the Chain Pier and Kemp Town, became eventually endangered, the road immediately between them and the edge of the cliff having actually given way, to such an extent, that, in some places, two carriages could scarcely pass each other. In order, at the same time, to prevent further degradation, and to obtain a greater width of road, the construction of a permanent sea-wall was determined on. The work was commenced in the year 1830, by excavating, at some distance in front of the cliff, the foundation for a wall 25 feet thick at the base, with an inclination on the face of 4 inches in each foot, in the vertical height of nearly 70 feet, and for upwards of a mile in extent. The wall was formed of concrete, composed of shingle from the beach and of mortar, containing three parts of sand to one part of chalk-lime. In working the concrete, the shingle and mortar were well mixed, in equal quantities, in a pug-mill, and then rammed into frames, which were raised as the construction proceeded. The interval, between the back of the wall and the face of the cliff, was filled up with chalk, or any other material that could be procured: the quantity required was, however, so great, that considerable delay occurred, which, with the want of funds and vexatious law proceedings, extended the period of construction over nearly six years. At the period of its commencement, there was scarcely any shingle along the shore, but by careful attention to the existing groynes, and putting down new ones, in good positions, not only a sufficient quantity of shingle was obtained, to complete the work, but before it was terminated there was a permanent 'full' of beach, of about 15 feet in depth, all along the front of the wall; and now, instead of the wall being in any danger from the action of the waves, there was a wide space between the wall and the high-water mark, upon which grass was growing; and the groynes were nearly all buried under the shingle they had arrested. This result showed what might be accomplished by a well-designed system of groynes; and similar results had been obtained by Mr. Wright, at Dover, at Cromer (Norfolk), and at other places.

Mr. W. B. ADAMS thought the conveyance of shingle along a beach, was a simple mechanical exercise of the projectile force of the wind-wave, and of the ground-swell, each class of wave probably performing its own special function. The largest pebbles were carried to the greatest distance, upon the same principle that, with sufficient force, a cannon-ball had a longer range than a musket-ball. A cannon charged with small shot, bullets, and a ball, would distribute its load in distances varying with the weight. The larger pebbles also presented interstitial surfaces upon which the force of

the water could act, just as stones were washed out of a sea-wall wherever crevices occurred ; whereas in proportion as the smaller shingle was rounded and ground down, the interstices diminished, and the weight and surface decreased, until the mass became nearly a solid body, on which the water had no hold. The most powerful waves, during storms, conveyed the larger pebbles high up, or far along the beach, until the force being exhausted, they were left in positions out of the influence of the retiring wave. The pebbles, within that influence, were carried back by the 'undertow,' to be again thrown up, or conveyed along, either until they reached a sufficiently horizontal spot for their deposit, or they were piled up in ridges, or fells, which reached a certain height and then toppled over seaward, advancing and forming points, or filling up bays. Such was the action upon the great mass of shingle, reached by every tide, whereas the larger pebbles were only reached at intervals by the waves raised by heavy gales.

Mr. J. PRICE had observed with great interest the features of the coast in the bay of Llandrillo, which was much exposed to the northerly gales, as also the appearances of the neighbouring shores of Llandulas, Abergele, Rhyl, &c., where, although the geological formations were exclusively carboniferous limestone, and a Silurian 'blue-stone,' the shingle was composed of an infinite variety of pebbles, systematically arranged in order of sizes, or weight. He would suggest, whether the larger pebbles being generally found high up, did not, in some degree, arise from their being subjected to the action of the waves, for a very short time, only at the top of the tide, whilst those lower down were under the triturating action, for some considerable time, twice during each tide, and were swept backwards and forwards during both ebb and flow.

It not unfrequently occurred, that there was a second row of large stones lower down the beach, and separated from the high-water ridge by zones of pebbles, gravel, and sometimes coarse sand : he was at a loss to account for this collocation, which deserved the same careful attention, as the remarkable permanent differences between portions of the same bay, and the temporary alterations produced by certain winds ; these he looked upon as self-registering apparatus, whose indications only required to be read off correctly, in order to solve many mysterious problems concerning tides and waves.

Mr. COODE had examined the locality of the shoal called 'The Shambles,' off Weymouth, and could not find any appearance of rock ; it appeared to consist of an aggregation of matters resulting from the confluence of tides, or currents ; the spot had since been examined by Mr. Deane, who would give an account of it.

He could not entirely agree with Mr. Redman's views relative to the Chesil Bank; but as his observations on it would occupy too much time for the present occasion, he would embody them in a paper, on the past and present state of that locality.

Mr. DEANE said, that on the morning of the 3rd December, 1851, he went from Portland Breakwater in a steam-vessel, with Messrs. Coode and Smith of the Portland Breakwater Works, to the Shambles shoal, off Weymouth, for the purpose of ascertaining the nature of the ground on that dangerous bank, and the practicability of placing some buoys, a beacon, or a light-vessel on it.

The bank was of considerable extent, and was always supposed to be composed of loose stones, or boulders, similar to the Chesil Bank.

After anchoring the steamer on the N.E. end, in 7 fathoms water, he descended to the bottom in the diving dress, with a basket and a long iron spit, for the purpose of sending up a portion of the soil and trying the quality of the ground below the surface.

On setting his foot on the ground he was surprised to find himself sink up to the ankles, in a mass of broken shells, so loose and moveable that there was an evident tendency from his weight on the ground to sink him deeper in. The water was very clear, and he observed, all round and to the extent to which he could see, that the shoal consisted of the same kind of material, apparently without a fibre of sea-weed.

The side of the bank had a most remarkable appearance, rising up out of the deep blue water in the form of broad shelves, or steps, one above another, about 8 feet wide and 16 inches deep, extending with great regularity in lines stretching east and west along the bank. These steps were all in motion, but with such a degree of order as could scarcely be conceived. Whilst he was on the upper part of the shoal, and the edge of the first step was about 6 feet to the northward from where he stood (the tide at the time running across to the southward), he observed the steep part of each step gradually sinking away and making towards him. Watching the singularity of this movement, and maintaining his position with some little difficulty, he marked the approach of the first step, which giving way from under his feet, passed to the southward, leaving him on ground 16 inches lower than before. Each step followed in the same order to the southward, still preserving the same uniformity of a step in height and width as when first seen.

He filled and sent up a bushel-basket nearly full of the soil, and

then forcing the point of the spit down about 4 feet into the ground, found the material to be the same at that depth.

The steamer was then moved to the middle part of the bank, and the same experiments were tried in a depth of 17 feet, with the same results. He also took up some soil of the same description from the west end, in 9 fathoms water.

These trials proved that the Shambles was not a bank of shingle, or boulders, but was composed of a mass of small and very light broken shells, almost entirely free from any particles of sand and gravel. This fact he believed to have been hitherto unknown: no human foot, in all probability, having ever previously alighted on its surface.

The extraordinary appearance of this easily-moved mass, standing in such regular order and succession, was a subject of deep interest, and gave rise to the reflection how a bank composed of a material nearly as light and moveable as water itself, could for ages have maintained its position and height above the common level of the bottom of the sea, exposed to the violence of strong gales and spring tides.

In answer to questions from the President, Mr. Deane said, that he had no opportunity of ascertaining the composition of the bank deeper than 4 feet below its surface, down to which it consisted entirely of clean broken shells. There would be little chance of obtaining decided information as to the nucleus of the bank, as, on account of the dangerous position, it was only practicable to descend at one time of the tide, and then to remain only for a limited period. He was lowered down out of a boat, with two weights of 56 lbs. each, attached to a rope, to enable him to steady himself. When he first observed the movement, he had left the rope, and was obliged to retreat to it for safety. The surface of the bank certainly did move; he was not deceived by any movement of his own; nor did he think the motion was caused by any local eddy, arising from the obstruction to the current, either by his body, or by the weights. The whole mass of the surface appeared to be in motion at the same time. There was very little current at the surface of the water, but it evidently increased as he descended, and the run of the tide appeared to strike the bank on the steep side and to run over it, as over a submerged groyne.

Mr. COODE explained, that the water was so clear, that they could see Mr. Deane walking about at the bottom; he came up once, to desire the weights to be increased, and it was not improbable that the eddy caused by the obstruction of the mass of weights

lowered on to a bank composed of such light material, might have set it in motion.

Captain O'BRIEN adhered to the fact of the larger pebbles being generally found at the top of the beach, unless under some peculiar circumstances. In a gale of wind the whole mass of shingle appeared to be carried upwards, by the flowing waves, but only the smaller pebbles were clawed back by the receding wave; thus it was, he believed, that the larger stones were generally found in a line at, or above, the high-water mark of ordinary tides.

Mr. HOMERSHAM directed attention to the general subsidence, or degradation, of those parts of the coast composed of chalk cliffs: this he attributed to the percolation of surface water, and when it was considered that each gallon of water, during its course, would take up a certain weight of chalk; that of the rain which fell, only a portion was carried away by the streams, the rest being absorbed by the denuded surface of the chalk district, that stratum being full of veins and fissures, and with innumerable streams oozing from the base of the cliffs all along the shore, it was not improbable, that even larger streams debouched from fissures below low water, and the quantity of chalk thus carried into the sea would, in his opinion, suffice to account for much of the subsidence of portions of the coast.

Mr. DEANE said, he had never observed any springs or influx of fresh water below low-water mark, nor any discoloration of the sea from filtrations of chalk: he had seen it rendered milky along the coast, after a heavy gale of wind in the vicinity of a chalk cliff, where there had been a recent fall, but rarely at any other time. On the day he descended on to the Shambles, the weather was perfectly calm, and the sea even clearer than usual, although all along the coast of Dorset and Devon it was generally so clear, that he could descend from a vessel and thoroughly examine the nail-heads and fastenings, and remove the barnacles, throughout the entire length.

As to the size of shingle, Mr. Deane almost invariably found the dimensions of the stones increase with the depth of the water, from a little below low-water mark. He never saw any stones moving under water at considerable depths; all appeared to have seaweed adhering to them, and exhibited every appearance of having been a long time at rest. In shallower water, within the direct influence of the waves, all the stones were rounded, evidently by attrition against each other.

Mr. HAWKSHAW thought there was some discrepancy in the accounts of the shingle on the Chesil Bank; Mr. Redman's state-

ment, corroborated by Sir Charles Lyell, was that the largest stones were found at the south-east end; Mr. Coode did not appear to agree in this: it would be well for the meeting to be in possession of the facts correctly.

As to Dungeness, it was very probable that the formation was in a great degree due to the action of the river Rother, which bringing down much clay and alluvial soil, commenced a delta, against which the shingle was now and would continue to be arrested, until it reached so far into deep water, that its further extension would be checked.

He thought, if cases like this were carefully examined, it would be found, that in the ratio of the formation of spits of shingle, or sand, there was always a corresponding degradation of the coast elsewhere, from the same influence, whether of wind-waves, or littoral currents.

Mr. COODE explained, that at the Chesil Bank the largest pebbles were found at the south-east end; but as a rule the smallest pebbles attained the greatest altitude, on the transverse section of the beach.

Mr. T. WEBSTER agreed with Mr. Hawkshaw, in his view of the formation of Dungeness Point: it must be conceded, that the accumulation of a mass of material, projecting on one side of an estuary, would produce some corresponding changes in the contour of other parts of the coast, and without entering into the question of whether the accumulation resulted from the action of wind-waves, or of tides, it must be admitted, that there were some general causes operating for the gradual growth of spits of this kind. The tidal currents and the great mass of water passing through the channel, were influenced by causes which could not vary much, under any ordinary circumstances, and although improved systems of drainage did, no doubt, bring larger quantities of land-water, in less time and with greater velocity, down the streams, and thus, for a short period, exert more power in the transporting of alluvial matter, that action was only temporary. Great effect was produced by the flow of water down estuaries, at certain times of the tide: the changes at the mouth of the Mersey were instances in illustration of this; and he would suggest, whether accretions of this kind might not be traced to some alteration of time of the flow of land-water, in reference to the usual run of the tide. Such an accretion once commenced, would speedily be augmented by the deposit of shingle and other matter, and in its turn affect other parts of the coast, by deflecting the tidal current and arresting the run of the wind-waves.

Mr. RENNIE believed, that the formation of both Dungeness and

Romney Marsh should be attributed, principally, to the counter-current of the tides; other causes, no doubt, lending aid. Dugdale mentioned the formation of the latter, and there could be no doubt that it was due to the action of the waves and tides, keeping back the land-waters, and thus creating a delta, upon and against which the shingle was deposited, until the outflow of the river had been changed, and the whole of the flat district behind became an extensive marsh.

Mr. J. SCOTT RUSSELL, in confirmation of his previous remarks, directed attention to the configuration of the beaches at Selsey Bill, and the Chesil Bank, where the shallow and shelving coasts around, would direct the waves, in approaching those two places, to embrace them and concentrate upon them whatever shingle had been picked up along the bottom, during their transit.

At Dungeness, the same contour was no longer perceptible, because the sea had already done its work, in covering the shallow parts, and the accretion, extending to the head, assumed a steeper profile in the deep water, where the annual advance was, therefore, much slower. He agreed with Mr. Rennie, in his view of the causes of the formation of Romney Marsh, the whole area of which had, most probably, been originally covered by the sea at high tides, though not to any considerable depth. The beach would form, gradually, as a strip nearest the high ground; a little grass and vegetation soon sufficing to fix the shingle and other material, so that the receding waves could not claw it off. This process would continue after each high tide, until the mainland advanced so far into the deeper water, that the waves had power to act upon the material, when the deposit would assume a different character, more like that at the Chesil Bank. At Dungeness, the accretion had proceeded, until the beach became extremely steep at the point; as was shown by the soundings close in-shore, and the advance had become slower, in proportion to the steepness of the face. Selsey Bill was another instance of this process of formation by deposit. The general uniformity of the channel and the great depth of water would probably prevent a similar extent of deposit at Portland Bill. It was his opinion, that the larger pebbles were drifted about and abraded in the depths of the West Bay, until they were sufficiently reduced in weight to be acted upon, first by extraordinary, and then by ordinary forces, when they were thrown upon the Chesil Bank, to be further abraded, the smaller stones being clawed off by the receding waves and the larger ones left for a time, as had been previously explained. As the force of an advancing wave was much greater than that of a retiring wave, it was evident, that both large and small pebbles could be thrown upon a bank, in positions

whence the small ones only would be clawed back, by ordinary tides, but in great storms both large and small stones would be moved: this might, in some measure, account for the apparent difference of observation, as to the position of the larger pebbles on the Chesil Bank. The observers may have visited the locality after a prevalence of very different weather, and of course the appearances would vary. It did not appear, from the Admiralty charts, that near these shingle beaches there were any tidal currents of sufficient velocity to move stones of the bulk of those forming the banks; therefore he was warranted in attributing their formation, chiefly, if not entirely, to the action of wind-waves, in conjunction with the local causes he had endeavoured to point out.

Mr. REDMAN said it should be observed, that the meeting of the tides, as described by Captain Beechey, though in the neighbourhood of Dungeness, oscillated over nearly sixty miles of the Channel, and, therefore, could have but little influence over the continued seaward progression of that extraordinary formation; and he must still retain the opinion, that the tidal currents did not exercise any considerable influence on the formation of shingle promontories and beaches. Almost all these promontories exhibited traces of having had old harbours to leeward, which had no doubt materially influenced their formation. Romney harbour, near Dungeness, and Pevensey harbour, at Langley Point, were instances of such relative positions.

He admitted, that his observations of the Chesil Bank, might have been made at a different period of the year from those by Mr. Coode, to whose experience of the features of the bank, during all seasons, he willingly deferred; it was his opinion, that the larger stones were generally found at the summit and to leeward (*i. e.*, to the eastward): this remark applied universally to all the shingle spits and banks on the southern shores of Great Britain. It would be very interesting to obtain for the Institution, series of sections of all the principal shingle beaches, after great storms and during different periods of the year, in order, practically, to set at rest a question apparently capable of such easy decision.

THE PRESIDENT said, he was convinced the thanks of the Institution would be unanimously offered to Mr. Redman, not only for his excellent paper, and the laborious researches he had not hesitated to undertake, for the benefit of the members, but also for directing their attention to a subject which was, theoretically and practically, of such general interest to Civil Engineers. It was frequently very difficult to trace present effects up to their previous causes, but it was most essential, in designing works connected with the action of the tides, or the waves. In the cases of the shingle banks alluded to,

he concurred in the opinion, that their origin might generally be traced to the denudation of a bank of primitive clay, or to the alluvial deposit from a river, forming a delta, upon which, in the course of time, the waves in breaking, deposited whatever they carried forward: thus a bank was formed, which gradually increased by the process which had been described, until almost all traces of the original cause were obliterated. At the Chesil Bank, at the Kicker Point, and generally at all the shingle beaches and deposits, between Chichester and Portsmouth, the basis was a bed of adhesive clay.

Another point of interest was to determine at what depth shingle did really travel, in the greatest quantity; and this would tend to elucidate the forces by which such vast masses were moved; his own opinion was, that shingle could scarcely be moved by the heaviest waves, in greater depths than three fathoms. How was it, that the shingle from the cliffs at Abbotsbury was conveyed across the West Bay, to the Chesil Bank? The solution of this, and similar instances, of the travel of shingle, in deep water, was most important to the consideration of many cases which engineers had to deal with, and he hoped the Institution would shortly be favoured with a paper on the subject by Mr. Coode, who, as the Resident Engineer of the Breakwater Works at Portland, had great opportunities of obtaining correct information. It had been observed, that in the numerous bays of the coast of Devon and Cornwall, the shingle of each bay remained perfectly distinct, when their headlands projected boldly into, at least, three fathoms of water. If, therefore, artificial groynes were carried low enough into the tideway, say to a depth of about four fathoms at low water, if that depth could be maintained, and if their inner ends could be carried high enough, the desired effect, of stopping the travel of shingle landward, might be attained.

He might, in connexion with the travel of shingle, mention that on one occasion, off the coast of Lyme, he observed a dark object moving slowly, at some considerable depth beneath the boat, and on towing it to the shore, it was found to be a large pebble of blue lias, held in suspension by the buoyancy of the sea-weed attached to it. It was not probable, that any quantity could travel by such means; but this might account for the accidental presence of stones from peculiar strata, in localities where it was difficult to give any adequate reason for their being found.

The President then expressed a hope, that the excellent example set by Mr. Redman, would be followed by many of the members, most of whom had it in their power to contribute papers of great interest, if they only recorded the observations made in the prosecution of their daily avocations.

January 27, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 865.—Description of an Iron Viaduct, erected at Manchester, on the joint station of the London and North Western, and the Manchester, Sheffield, and Lincolnshire Railways. By **ALFRED STANISTREET JEE**, M. Inst. C. E.¹

THIS Viaduct was designed, by the Author, for the purpose of extending the accommodation of the goods station of the London and North Western, and the Manchester, Sheffield, and Lincolnshire Railways. The Act of Parliament, giving the necessary powers, was passed in 1846, but owing to want of funds, the work was not commenced till the beginning of 1849, when the increased traffic rendered additional space indispensable.

The viaduct forms an addition of 36 feet to the breadth of the station, throughout nearly its entire length, of about 700 feet; and gives three additional lines of rails on the upper level, without interfering with those below, on the level of the street. The station is formed on brick arches, at a height of about 30 feet above the streets. These arches are used as warehouses for goods, and the rails below communicate with those above, by means of hoists worked by stationary engines.

It was essentially necessary, in widening the station, that there should be no interference with the lines, either on the top, or the bottom level, and an extra width was, therefore, extended over the whole length of the goods station. The system of construction was by placing cast-iron pillars at intervals of 20 feet from each other, along the outside of the space to be enclosed. Cast-iron transverse girders of 31 feet 7½ inches clear span were then inserted at the proper level, with one end of each girder resting upon the brickwork of the existing arches, and the other end upon a pillar.

To these transverse girders were attached smaller longitudinal girders, also of cast iron, in such positions that one girder should be under each rail, and in order to give stability to the structure, in the direction of its length, brick abutments were erected at each end.

The longitudinal girders and outside cornices, being built into the abutments, afforded an effectual stay to the pillars, and kept the whole structure steady; and in order to prevent the transverse girders and pillars from moving laterally, they were fastened to the brickwork of the existing arches by wrought-iron tie-rods. The foundations of the pillars were composed of brickwork, and were

¹ The discussion upon this Paper extended over a portion of two evenings, but an abstract of the whole is given consecutively.

laid upon the red sandstone rock, which is at a depth of about 30 feet from the surface, at the west end, and about 10 feet from the surface, at the east end.

Upon the top of the longitudinal girders half-balk Memel timbers were bolted, and the whole space was planked with Memel deals, 3 inches thick, laid with a slight fall towards the outside gutters; well caulked and covered with a layer of tar and sand. The chairs were spiked to the planking, and where necessary, on account of its slope, oak packings were used, to bring them up to the proper level. In every case, care was taken that the spikes should have a good hold on the longitudinal timbers. In order to accommodate the traffic, it was necessary to have twenty-one turn-tables, which were fixed between the girders, and were of the simplest construction; moving round a hardened-steel pivot in the centre, and upon six rollers of 12 inches diameter on the outside. It was necessary, in order to communicate with the Sheffield Company's warehouses, to carry two lines of rails over Sheffield Street, at right angles to the main station. This was done by means of cast-iron girders, each 42 feet 5 inches span, resting on iron columns. It being more convenient to the contractors to cast each girder in two parts, a very ingenious plan was adopted for joining them. The girders were increased in depth, at the joint, by adding to their upper portion; and the joints, being planed true, were bolted together. At the bottom side of the lower web, a recess, of an elliptic form, was cast, into which a wrought-iron strap was put, whilst at a red heat, and the contraction, on cooling, made a very perfect joint, the wrought-iron strap being just in the proper place to resist the tension of the girder. This crossing of Sheffield Street also forms a transverse stay to the whole structure.

At the western end of the station is situated a large warehouse, belonging to the Sheffield Company, and in order to communicate with this, it was necessary to carry the three lines of rails across Store Street. The space to be spanned was 65 feet, and it was accomplished by means of wrought-iron girders, of a novel construction (Wood-cuts, Figs. 13, 14, and 15, Table V., page 232). The top part of each girder is a cylindrical tube, of 2 feet diameter, composed of boiler-plates half an inch in thickness. To the underside of this tube the middle web is riveted; it is formed of plates five-sixteenths of an inch thick, and 3 feet 6 inches deep. The bottom flange, 20 inches wide, is riveted to these plates; it consists, at the middle portion, of three thicknesses of plates three-eighths of an inch thick, diminishing to one thickness at the ends. The whole is put together with angle-iron, and the cylindrical form of the tube is preserved, by riveting the ends of the plates to internal angle-iron hoops.

[1851-52.]

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The several parts of these girders are so arranged, that the whole is very accessible, and both the top and the bottom are well adapted to resist the strains they are respectively required to bear. The girders rest on large wall-plates, bolted down to the brickwork. Each of them was tested with a weight of 60 tons on the centre, and the deflection was not greater than one inch. The lines of railway are carried by timber cross-pieces, supported by angle-iron brackets, riveted to the middle web of the girders.

The whole of the cast-iron work is of 'Stirling's toughened iron,' and the contract was well executed by Messrs. Robinson and Russell, every part being fitted with the greatest accuracy, and each girder was tested to at least twice the load that can ever be brought upon it, the breaking weight being six times the greatest load it is calculated to carry. The total cost of the structure, including the foundations and laying the rails, was £13,868 13s. 4d., or nearly £20 per foot lineal.

The quantity of cast-iron, shown in the original design, was 1157 tons, but the contractors being permitted to use 'Stirling's toughened iron,' a considerable saving in the weight was effected, the actual quantity used being only 859 tons; whilst the strength of the girders was not diminished by the change, as was proved by the testing, which showed that they were fully capable of supporting the required weight.

The following is a detail of the quantities, and of the cost of each part of the structure:—

DESCRIPTION.	Quantity.	Price.	Amount.
		£. s. d.	£. s. d.
Excavating foundations . .	2,782 cub. yds.	0 2 6	360 5 0
Brickwork	1,650 ,,	0 15 0	1,237 10 0
Footings	321 ,,	1 0 0	321 0 0
Ashlar	513 cub. feet	0 1 4	34 4 0
Cast-iron ('Stirling's tough- ened iron')	859 tons 1 cwt.	8 7 7½	7,199 18 4
Wrought-iron, in bolts, tie- rods, &c.	19,040 lbs. . .	0 0 4	317 6 8
Wrought-iron girders over Store-street.	44 tons 15 cwt.	22 0 0	984 10 0
Memel timber	4,642 cub. feet	0 2 10	657 12 4
,, planking, 3 in. thick	25,449 sup. feet	0 1 0	1,272 9 0
Laying three lines of rails .	250 linl. yards	0 3 0	37 10 0
Turntables, fixed.	21 ,,	45 0 0	945 0 0
Iron staircase, complete. .	..	..	75 8 0
,, fence railing and gates.	..	..	426 0 0
Total . .	..	.. £	13,868 13 4

The Paper is accompanied by an Appendix, containing the details of the testing of the girders, and is illustrated by diagrams of the forms and sections of the girders, whence the woodcuts (Figs. 1 to 15) are compiled.

APPENDIX.

TABLES showing the RESULT of the TESTS applied to each GIRDER.

TABLE I.

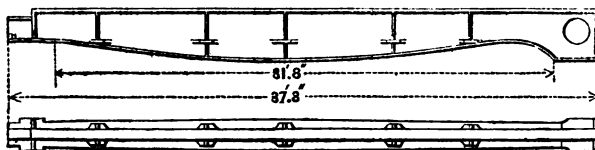
TRANSVERSE CAST-IRON GIRDERS.

Fig. 1 shows Elevation and Plan.

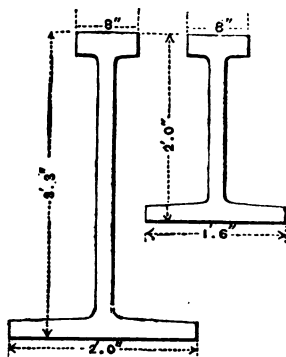
,, 2 ,, Section at centre.

,, 3 ,, Ditto at neck.

Fig. 1.



Figs. 2, 3.



	Feet.	Inches.
Total length of girder	37	3
Span	31	8
Depth at centre	3	3
Thickness of vertical web	0	2
,, top flanch	0	2 $\frac{1}{4}$
Breadth of ditto	0	8
Thickness of bottom flanch	0	2 $\frac{1}{4}$
Breadth of ditto at centre	2	0
,, ,, at ends	1	6

Weight of each girder 7 tons 10 cwt.

Each girder was tested, first with 28·80 tons, and then with 67·88 tons, applied at the centre, and the deflection and set recorded in inches and decimals; the results are given in the following Table :—

No.	Deflection.	Set.	No.	Deflection.	Set.	No.	Deflection.	Set.	No.	Deflection.	Set.
1	0·26	0·00	9	0·32	0·00	17	0·30	0·00	25	0·22	0·00
„	0·60	0·10	„	0·68	0·10	„	0·65	0·10	„	0·52	0·05
2	0·20	0·00	10	0·30	0·00	18	0·27	0·00	26	0·25	0·00
„	0·55	0·00	„	0·70	0·12	„	0·60	0·08	„	0·58	0·08
3	0·15	0·00	11	0·28	0·00	19	0·52	0·00	27	0·30	0·00
„	0·50	0·05	„	0·52	0·05	„	0·68	0·12	„	0·62	0·15
4	0·12	0·00	12	0·28	0·00	20	0·50	0·00	28	0·30	0·00
„	0·48	0·08	„	0·52	0·10	„	0·65	0·08	„	0·62	0·10
5	0·20	0·00	13	0·28	0·00	21	0·35	0·00	29	0·22	0·00
„	0·42	0·08	„	0·65	0·08	„	0·62	0·08	„	0·52	0·10
6	0·20	0·00	14	0·32	0·00	22	0·38	0·00	30	0·26	0·00
„	0·48	0·10	„	0·70	0·12	„	0·65	0·10	„	0·55	0·10
7	0·25	0·00	15	0·28	0·00	23	0·25	0·00	31	0·26	0·00
„	0·60	0·08	„	0·62	0·12	„	0·55	0·05	„	0·55	0·10
8	0·22	0·00	16	0·25	0·00	24	0·32	0·00	„	„	„
„	0·58	0·00	„	0·60	0·10	„	0·65	0·10	„	„	„

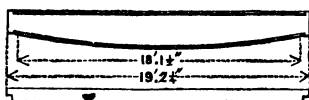
TABLE II.
LONGITUDINAL CAST-IRON GIRDERS.

Fig. 4 shows Elevation and Plan.

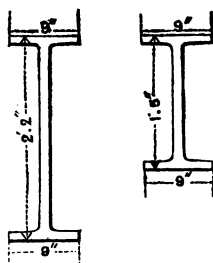
„ 5 „ Section at centre.

„ 6 „ „ at end.

Fig. 4.



Figs. 5, 6.



	Feet.	Inches.
Total length	19	2 1/4
„ „ between supports	18	1 1/2
Depth at centre	2	2
„ „ at ends	1	5
Thickness of vertical web	0	1
„ „ top flanch	0	1
Breadth of „ „	0	9
Thickness of bottom flanch	0	1 1/2
Breadth „ „ „	0	9

Weight of each girder 1 ton 4 cwt.

These girders were tested with a weight of 28·80 tons, applied to the centre, and the deflection recorded in inches and decimals; the results are given in the following Table:—

No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.
1	0·27	24	0·30	47	0·32	70	0·25	93	0·30	116	0·25	139	0·30
2	0·22	25	0·25	48	0·20	71	0·30	94	0·26	117	0·30	140	0·38
3	0·23	26	0·30	49	0·25	72	0·30	95	0·26	118		141	0·35
4	0·25	27	0·26	50	0·35	73	0·25	96	0·28	119		142	0·35
5	0·30	28	0·39	51	0·28	74	0·30	97	0·28	120		143	0·30
6	0·30	29	0·30	52	0·22	75	0·28	98	0·18	121		144	0·28
7	0·30	30	0·30	53	0·18	76	0·30	99	0·18	122		145	0·30
8	0·32	31	0·28	54	0·20	77	0·32	100	0·30	123		146	0·30
9	0·30	32	0·35	55	0·28	78	0·30	101	0·28	124		147	0·30
10	0·25	33	0·32	56	0·25	79	0·28	102	0·28	125		148	0·28
11	0·30	34	0·32	57	0·18	80	0·25	103	0·25	126		149	0·28
12	0·25	35	0·30	58	0·28	81	0·28	104	0·28	127		150	0·30
13	0·20	36	0·32	59	0·30	82	0·30	105	0·28	128	*	151	0·28
14	0·30	37	0·28	60	0·30	83	0·28	106	0·30	129		152	0·30
15	0·22	38	0·28	61	0·25	84	0·30	107	0·28	130		153	0·28
16	0·25	39	0·28	62	0·20	85	0·25	108	0·30	131		154	0·30
17	0·20	40	0·25	63	0·22	86	0·18	109	0·28	132		155	0·32
18	0·22	41	0·32	64	0·30	87	0·20	110	0·30	133		156	0·28
19	0·21	42	0·25	65	0·30	88	0·28	111	0·28	134		157	0·28
20	0·22	43	0·28	66	0·25	89	0·28	112	0·30	135		158	0·28
21	0·28	44	0·35	67	0·22	90	0·22	113	0·28	136		159	0·30
22	0·20	45	0·28	68	0·25	91	0·26	114	0·20	137		160	0·30
23	0·22	46	0·28	69	0·25	92	0·30	115	0·25	138	0·30	161	0·30

There was no permanent set observable in any of these girders.

TABLE III.

SHORT CAST-IRON GIRDER,

carrying the end of the centre Girder of the Sheffield-street Bridge.

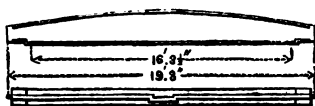
Span, 16 feet 4 inches.

Fig. 7 shows Elevation and Plan.

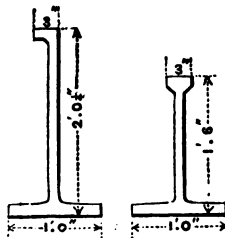
„ 8 „ Section at centre.

„ 9 „ „ at end.

Fig. 7.



Figs. 8, 9.



* These girders were tested, after their erection, with the specified weight of 10 tons, and the deflection in no case exceeded 0·10.

IRON-VIADUCT.

	Feet.	Inches.
Total length	19	3
,, between supports	16	3½
Depth at centre	2	0½
,, at ends	1	6
Thickness of vertical web.	0	1½
,, of top flanch	0	1½
Breadth of ditto	0	3
Thickness of bottom flanch	0	1½
Breadth of ditto	1	0

Weight of girder, 1 ton 5 cwt.

This girder was tested, after the completion of the bridge, by weights varying from 10 to 20 tons applied at its centre, in addition to what it already supported (about 6 tons 10 cwt.). The deflection was recorded in inches and decimals, and is given in the following Table:—

Weight.	Deflection.	Set.
10	0·05	..
12	0·06	..
14	0·07	..
16	0·09	..
18	0·10	..
20	0·11	0·00

TABLE IV.

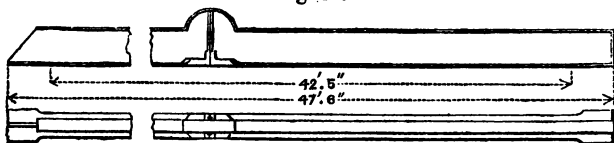
CAST-IRON GIRDERS—Sheffield-street Bridge.

Fig. 10 shows Elevation and Plan.

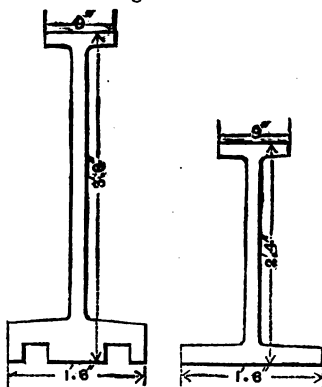
,, 11 ,, Section at centre.

,, 12 ,, ,, at ends.

Fig. 10.



Figs. 11, 12.



	Feet.	Inches.
Total length	47	6
,, between supports	42	5
Depth at centre	3	6
,, at ends	2	4
Thickness of vertical web	0	1½
,, of top flanch	0	1½
Breadth of ditto	0	9
Thickness of bottom flanch	0	2
Breadth of ditto	1	6

Weight of each girder, 7 tons 10 cwt.

Each girder was tested with a weight of 18·83 tons, applied at the centre, and the deflection was recorded in inches and decimals. The following Table gives the results:—

No.	Weight.	Deflection.	Set.
1	18 83	0·75	0·06
2	18·83	0·93	0·13
3	18·83	0·93	0·13

TABLE V.

WROUGHT-IRON TUBULAR GIRDERS—Store-street Bridge.

Fig. 13 shows Section of the Girder.

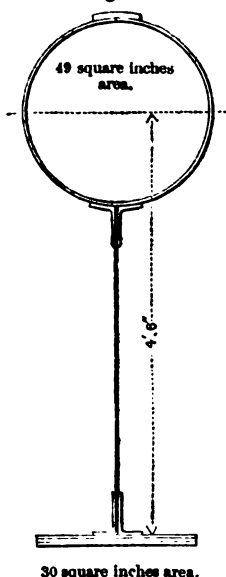
,, 14 ,, Elevation.

,, 15 ,, arrangement of Plates of Bottom Flanch.

	Feet.	Inches.
Total length of girder	71	0
,, span	65	0
Depth from centre of tube to bottom flanch	4	6
Diameter of tube (outside)	2	0
Thickness of tube, 3 plates at each end	0	0 ⁷ / ₁₆
,, ,, other 7 plates	0	0½
Depth of vertical web	3	6
Thickness of web, 2 plates at each end	0	0 ³ / ₁₆
,, ,, other 5 plates	0	0½
Width of bottom flanch	1	8
Thickness of ditto at centre	0	1½
,, ,, at ends	0	0½

Weight of each girder, 11 tons 4 cwt.

Fig. 13.



Two of these girders, B and C, were tested in London, with weights of 33 tons and 60 tons on the centre of each. Subsequently, the whole of the girders were tested, with weights equally distributed. The weights in the latter case have been halved, so as to bring them more nearly to correspond with the former, and the results of the whole are given in the following Table. The deflections are given in inches and decimals.

No.	Weight.	Deflection.	Set.
A	10·75	0·1550	0·000
B	19·25	0·3250	..
„	33·00	0·5000	..
„	35 50	0·6250	..
„	60·00	0·9500	0·000
C	16·25	0·2875	..
„	33·00	0·6200	..
„	38·75	0·7000	..
„	60·00	1·0100	0·000
D	12·50	0·2250	0·000

Fig. 14.

Elevation of Wrought-Iron Girder.

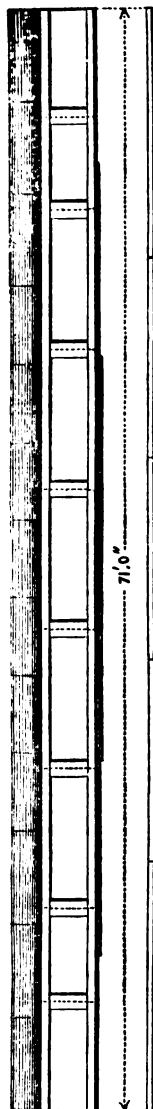


Fig. 15.

Arrangement of Bottom Plates.

Mr. SCOTT RUSSELL said the structure, which had been described, was tested very carefully, both in all the separate portions and collectively, when the whole was complete and erected.

The system of toughening the cast-iron, by an admixture of a certain portion of wrought-iron, under the process introduced by Mr. Morris Stirling, had been tried with success, and although it was possible to produce as strong a casting, by the mixture of certain irons with 'Blaenavon pig,' it could not be done so economically as by Stirling's system.

The general arrangement of the structure was, he thought, very satisfactory; foot for foot, the bridge forming part of the viaduct, was as strong and stiff as any wrought-iron girders with cellular tops, and it was admitted, that the use of longitudinal-beams, on the arches, gave a general bearing which could not have been obtained in any other manner.

Mr. Scott Russell, with the assent of Mr. Jee, had taken advantage of the opportunity here afforded, to ascertain, by experiment, whether the 'box' form was commercially the best for wrought-iron girders, for such comparatively small spans as 65 feet, and with so limited a depth as 4 feet 6 inches. The square cellular top and double sides, of the ordinary box-girder, did not afford free access to the interior, to enable it to be repaired, or painted, therefore he wished to try a form, which, whilst offering these facilities, should possess at least as great strength, with less weight of metal. He had therefore adopted the form, Figs. 13, 14, and 15, which had been described (pages 231-2). The cylindrical form of the top prevented any tendency to 'buckling,' and being 2 feet in diameter, it was large enough to admit a man, and allow him to work in it; the single vertical web was, he submitted, simpler than the two sides of the box-girder, affording at the same time free access for painting; and the transverse web, or bottom flanch, presented the best form for resisting tension.

In proportioning the material for girders of this form, the substance of the upper cylindrical tube, and of the bottom flanch, should be thickest at the centre, and thinnest at the extremities, whilst the middle web should be thinnest at the centre and thickest at the ends.

The tables of deflection gave very satisfactory results, and the correctness of the experiments upon the girders, before they were fixed, were confirmed by trials with trains of engines and heavily-loaded carriages, which were subsequently placed on the structure, when it was completed.

Mr. FOWLER corroborated the favourable opinion, not only of the

structure generally, but of the manner in which the work had been executed by Messrs. Robinson and Russell. He was inclined to approve the innovation of the enlarged cylindrical top to the girder, chiefly because of the facility it afforded for examining the interior, so as to paint it and prevent oxidation; this was of considerable importance, and should be insisted upon in all box girders.

The foundations for the structure were very troublesome: under some of the pillars it had been necessary to go to the depth of nearly 30 feet, through made ground, which it was thought advisable to traverse, and (where it was practicable) to sink as far as the sandstone.

Mr. SIMPSON, V.P., explained that the foundation went through the marl of that district, which was frequently interspersed with loose sand, and therefore, for a structure of that importance, it was prudent to go down to the sandstone rock.

Mr. R. RUSSEL explained, that for the major part of the foundations there was a depth of a few feet of good soil, and then a considerable depth of loose sand, and sometimes old-made ground. It had been thought strange, that piles should not have been driven, instead of excavating to such great depths. This arose from its being generally believed, that the culvert of an old stream, called 'Shooter's Brook,' traversed the site of the abutment of the viaduct; this was found, eventually, not to be the case, but under the original impression of its being there, piling was considered unsafe.

Mr. BIDDER observed some apparent discrepancies in the tabular results of the experiments, and wished to be informed how they were conducted.

Mr. R. RUSSEL explained, that all the beams were tested, either by hydraulic pressure, or by absolute weights, before they were fixed; subsequently the entire viaduct was tested, by bringing six locomotive engines and tenders, weighing together, 195 tons, down in a body, along the lines of rails, as far as the end of the Store Street Bridge.

The two engines on the outside line, each weighing 30 tons, were then sent on to the bridge. This weight of 60 tons was distributed unequally upon the girders, on account of the rails being nearer to one girder than to the other; girder A, in a line with the outside columns, thus received about 21·5 tons which caused a deflection of 0·155 inch, whilst girder B had to bear 38·5 tons, under which load the deflection was 0·32 inch.

The two engines on the middle line, weighing respectively 30 tons and 35 tons; were then brought on abreast of the others. In this case, the load of 65 tons being equally divided, the weight upon B

became $38.5 + 32.5 = 71$ tons, under which the deflection was 0.625 inch; whilst girder C, with a load of 32.5 tons, deflected 0.2875 inch.

The two engines on the inner line were then brought forward, their weight was 35 tons each = 70 tons; of this load, girder C received 45 tons, making the weight upon it $32.5 + 45 = 77.5$ tons, under which the deflection was 0.7 inch; whilst girder D, under a load of 25 tons, deflected 0.225 inch.

There was no increase in these deflections, during the time the engines remained upon the bridge, and when they were removed, the greatest settlement was found to be 0.0375 inch, in girder C, and that probably arose from the yielding of a layer of patent felt, which was placed under the ends of all the girders. Shortly after the experiment, it was found, that all the girders had more than recovered the amount of settlement, being considerably higher than at the commencement of the trials, the difference being due to a change of temperature, by which these girders were always sensibly affected.

Comparing the results of these trials with those of the experiments on the girders separately, it will be seen, that the deflection, as compared with the London experiments, was in one case greater, and in another case less. The different tests, therefore, agreed as well as could be expected, considering the widely dissimilar circumstances under which they were applied.

The following table exhibits the results of the trials, both in London and in Manchester. In the former experiments, Nos. 4, 5, 8, and 9, the weights were applied at the centre of the girder, whilst in the latter, Nos. 1, 2, 3, 6, 7, and 10, the load was uniformly distributed, so that the former results required (practically) to be doubled, in order to make them correspond with the latter, and this had been done in the Table.

Experi- ment.	Girder.	Weight.	Actual Deflection.	Calculated Deflection.	Actual Deflection per Ton.
1	A	21.5	0.155	0.187	0.00729
2	B	38.5	0.325	0.335	0.00844
3	"	71.0	0.625	0.618	0.00880
4	"	66.0	0.500	0.574	0.00757 } London
5	"	120.0	0.950	1.044	0.00791 } Experiments.
6	C	32.5	0.2875	0.283	0.00884
7	"	77.5	0.7000	0.674	0.00903
8	"	66.0	0.620	0.574	0.00939 } London
9	"	120.0	1.010	1.044	0.00916 } Experiments.
10	D	25.0	0.225	0.217	0.00900
					0.00854 Mean.

Mr. SCOTT RUSSELL admitted, that the load, said to have been placed on the centre of the girders, had not been suspended from one point, inasmuch as the London experiments were made by piling up a cubic mass of 'kentledge' iron in the centre, for a width of 6 feet, and then filling the angles on each side with pig-iron, which was also piled up in a conical form on the top of the mass of kentledge; thus, although the load was spread over a length of nearly 20 feet, the chief weight bore directly on the centre: and in the Manchester experiments the locomotives were so arranged as to distribute the load as uniformly as possible, yet the accordance between the results was remarkable, and the mean deflection per ton was only 0.00854 inch.

With respect to the form of the wrought-iron girder, Mr. Eaton Hodgkinson's experiments showed, that a cylindrical tube, of good proportions, resisted buckling better than a square cellular box girder with a top, in the ratio of 16 to 12. This, in addition to the practical facilities offered for examining the inside of the tube, induced Mr. Scott Russell to prefer the cylindrical top for girders of moderate spans.

Mr. POLE stated, that he had compared the experiments on the Store-street girders with those on the model tube constructed before the building of the Britannia Bridge,¹ and with trials of a girder bridge erected by Mr. Fowler, over the Old Ancholme, on the Manchester, Sheffield, and Lincolnshire railway.

The dimensions in each of these cases were different from those of Mr. Scott Russell's girders; but it was easy, by simple known rules to arrive at means of fair comparison. The deflection of a tubular girder would vary directly as the cube of the length, and inversely as the square of the depth; and it might also be assumed, without important error, to be proportional inversely to the area of the section of the top and bottom flanches.

Reducing, therefore, the before-named experiments by these rules, and comparing them with the results of the trials of the Store-street girders, the latter were found to be about equal in stiffness to the former, proving that the arrangement adopted was a favourable one.

Mr. RIDDER contended, that the method of testing the girders could not be considered as sufficiently accurate for theoretical calculations, although practically the results appeared satisfactory. He objected to its being assumed, that the whole area of the metal of the top tube was in an equal state of compression; if the top had

¹ Vide "Clark's Britannia and Conway Tubular Bridges," 4to. 1850.

been formed of a tube of cast-iron of smaller diameter that might have been assumed.

The practical question was, whether the proposed form was a superior distribution of the metal, to that of plain and properly-proportioned top and bottom flanches, connected by a centre web : he did not think that it was so, and he preferred the latter form, precisely for the reasons advanced in favour of the cylindrical tubular top, because the plain flanches were at all times accessible for repair and for painting, and the metal could be so distributed as to offer the most uniform resistance, both to compression and tension.

Captain SIMMONS, R.E., said, it had been his duty to inspect many of these wrought-iron girders, and he thought them generally excellent applications of metal. He believed, that Mr. Brunel was among the first to adopt the cylindrical top for girders of this description.

Mr. BRUNEL, V.P., stated, that it was difficult to say by whom the cylindrical tops for girders had been first introduced, but if he had not originated them, he believed he was among the first to use them on a large scale, and he must own that he was fond of them, provided the cylindrical tube was not of too large a diameter, in which case Mr. Bidder's objections would be valid, as the axis would be too far from the upper part of the periphery of the tube.

He had employed girders with a top tube of a triangular section, with the apex downwards, and by using thicker plate, the greater mass of metal was thrown into the flat top, to resist compression, whilst the sides of the triangle were useful to prevent buckling, which might occur with plain flanches, unless they were of considerable thickness. He was, however, disposed to prefer a segmental top, for a girder of moderate size. Practically he found, that boiler-plate and angle-iron now offered such facilities, that it would almost tax the ingenuity of an engineer to design a bad wrought-iron girder.

With respect to the tests, he could not receive the tabulated results as representing accurately the effects of a load in the centre, when that load had been spread over at least 12 feet ; it was evident that the span was virtually diminished, as in spite of the pyramidal piling up of the kentledge and pig iron, the mass would act somewhat like a loaded arch, whose abutments were 12 feet apart along the girder. Such a method of testing would give a difference of nearly 10 per cent. in the results. Nor did he think, that the test by the locomotives and tenders could be received,

as giving very correctly the results of a load equally distributed, as there was a much greater weight on one pair of wheels than on another pair. Still the test was practically useful, and the result, shown in the deflection, was satisfactory.

Mr. SCOTT RUSSELL thought he had not unduly estimated the practical advantages of the form of girder, and if it was imagined, that in a diameter of 2 feet the axis of the tube was too much lowered, as the calculations were all made to the centre of the section of the cylindrical top, it would be easy to add to the thickness of the upper row of plates and make the rest of the periphery thinner. The diameter of 2 feet would suffice for a girder of much greater span than those under discussion. He was not, however, of opinion that practically a diameter of 2 feet was too large, and it certainly offered great facilities for construction, and for subsequently keeping the girder in order.

He had foreseen the objections as to the theoretical reduction of the results, by the spreading of the load over the surface, but thought the precautions taken, in piling up the kentledge and pig-iron pyramidally, had really compensated, in a greater degree than it had obtained credit for.

Mr. HAWKSHAW was so fully impressed with the necessity of great accuracy, in testing girders for railway purposes, that he had availed himself of the experience and skill of Mr. Eaton Hodgkinson, in proving the girders for a cast-iron viaduct, erected from his designs, at Salford, a description of which he would prepare for the next meeting.¹

The experiments were made with a very simple, but efficient steel-yard apparatus, by which the pressure was applied critically to one point in the girder, and the results were easily read off.

Mr. MORRIES STIRLING said, as the cast-iron girders were made of metal toughened by the system he had introduced, he might be permitted to explain, that their additional strength was derived from an admixture of scraps of wrought-iron, which becoming intimately incorporated with the fluid cast-iron, whilst running from the blast-furnace, formed a mixture, which when remelted and run into castings, produced a metal, possessing great strength, deflecting less than ordinary cast-iron, under similar weights, and having less permanent 'set.' The expense of the process did not exceed ten, or twelve shillings per ton, and the advantages were incontestable.²

¹ Vide page 241.

² In the Report of the Commissioners, appointed to inquire into the application of Iron to Railway purposes (1849), are the following experiments, made

As it appeared desirable to have, for the upper part of tubular wrought-iron girders, a material possessing to some extent the incompressibility of cast-iron, he would suggest the addition of tin, to the iron in the puddling furnace; the plate-iron, so produced, would

by Mr. Eaton Hodgkinson, on the comparative increased strength and tenacity of the toughened iron :—

CAST-IRON.

Bars 10 feet long, 2 inches square, and with the supports 9 feet apart, broke as follows :—

	lbs.
Blaenavon iron, No. 2	1,220
Low Moor iron, No. 1	1,207

Bars cast at Warrington, composed as follows :—

Madeley Wood, 8 parts	
Lilleshall 6 „	} 1,374
Pontypool 3½ „	
Charcoal iron 5 „	

Mr. Morries Stirling's Second Quality :—

Calder hot blast, No. 1, with 20 per cent. of malleable scrap	2,174
---	-------

This iron is termed “second quality,” because a still stronger mixture, more especially for large castings, is produced by employing No. 3 iron with the requisite proportion of malleable scrap. In a series of experiments made at the Dundyyan Works, and described at page 416 of the Commissioners' Report, the strength of bars of this mixture, of the same size as the foregoing, is shown to be much greater, the breaking weight being 2,601 lbs. It will be observed how nearly the Dundyyan experiments correspond with Mr. Hodgkinson's, as the two series of experiments on No. 1 Toughened Iron will show :—

	lbs.
Mr. Eaton Hodgkinson's experiments	2,174
Dundyyan experiments	2,152
Ditto	2,234

MALLEABLE IRON.

The following abstracts of experiments are also taken from the same Report, page 417 :—

	Breaking Strain in Tons per square Inch.
Average of Mr. Jesse Hartley's experiments at Liverpool, on many sorts of malleable iron	23·23
Average of S. C. Crown Iron from numerous trials at Woolwich Dockyard	24·47
Average of best Dundyyan bar	24·33
„ Mr. Morries Stirling's best quality	27·81
„ Ditto another quality	27·70

Sec. Inst. C. E.

be found to possess great hardness and stiffness, and would be useful where it was subject to compression. He thought also, that by introducing an alloy in the working of the iron, the oxidation of the metal might be reduced.

Mr. SIMPSON, V.P., said, that he found painting wrought-iron work an endless task, and even then the interior of the joints and the pin-holes could not be reached; for roofs he had, therefore, adopted the old system of having each piece warmed, dipped into heated common oil and dried; this process gave a glaze almost like varnish to the surface, the paint adhered better afterwards, and it required to be much less frequently repeated.

The PRESIDENT expressed his pleasure at the practical nature of the paper and of the discussion, and the obligation of the meeting for the offer of Mr. Hawkshaw, to add to the information on the subject, by the description of his viaduct at Salford; he trusted, that this good example would be followed, and that members would come to the meetings, prepared with descriptions of works, analogous to those which might be under discussion, as it was by this kind of comparison, that the advantages of the meetings at the Institution were rendered most apparent.

He thought, that in fixing the form and the minimum thickness of metal, that could be employed to carry a certain load, the question of corrosion should be carefully considered, as it would have great influence on the durability of wrought-iron structures. In designing works in India, where the climate had an extraordinary effect on metal exposed to the weather, he had been careful to make ample allowance for the greater amount of corrosion than would take place in Europe.

February 3rd, 1852.

JAMES SIMPSON, Vice-President, in the Chair.

The following candidates were balloted for, and duly elected :—

Captain Christopher Claxton, R.N. ; Captain Henry Cunliffe Owen, R.E. ; Lieut. Edward Fraser, B.E. ; Lieut. William Kendall, B.E. ; and Peter Paterson, as Associates.

After the renewed discussion on Mr. Jee's paper, which occupied the greater part of the evening, Mr. Hawkshaw brought forward the paper he promised at the last meeting.¹

No. 865 A.—“Description of a Cast-Iron Viaduct, or Colonnade, constructed at Salford.” By JOHN HAWKSHAW, M. Inst. C.E.

In effecting a junction, in the year 1842, between the Liverpool and Manchester, Manchester and Leeds, and Manchester and Bolton Railways, at Salford, it became necessary to carry the Junction Railway, either through the station of the Manchester and Bolton Company, or parallel with and close to it.

There existed almost insuperable objections to passing through the station, which, besides being already too narrow, was bounded on both sides by public streets, so that it was imperative to devise other means of accomplishing the object. The difficulty was at length overcome, by an agreement with the authorities of the town, for which an Act of Parliament was afterwards obtained, for permission to place a line of cast-iron columns along the centre of Upper Booth Street, and by using these columns for a support on one side, and the existing brick viaduct, which ran along the north side of the street, as a support for the other, to construct thereon a viaduct to carry the railway, in such a manner, as to allow the street beneath to remain open to the public, as before, the only obstruction being the columns, placed in a line along the middle, which, with the superstructure above, had the effect of converting one-half of the street into a covered way.

The columns are placed in pairs, opposite to each pier of the viaduct, and transverse girders are fixed across from each column, and let into the brickwork of the viaduct, belonging to the Manchester and Bolton Company. The columns forming each pair, stand 7 feet apart, from centre to centre, and the spaces between each pair, and consequently between each pair of transverse girders resting upon them, are 29 feet in width ; these spaces are each crossed by four longitudinal girders, so arranged as to be 7 feet

¹ Vide *ante*, page 238.

apart, from centre to centre, and the uniform spaces, of 7 feet wide, between all the transverse and longitudinal girders, are filled in with flat brick arches set in cement, on which, after being ballasted, the permanent way was laid.

The outer longitudinal girder carries a high screen, or fence, composed of cast-iron plates, each 9 feet high, 5 feet broad, and 1 inch thick, overlapping each other for about 6 inches, but so as to present a smooth surface next the street, and the plates, besides being firmly bolted down to the girders, are securely fastened together, at the overlapping joints, by iron rivets.¹

The position of the columns happening to be exactly over the line of the common sewer of the street, it became necessary to construct a new sewer, and to take the foundations for the column down to the sound bottom, a depth of about 15 feet.

The total length of the viaduct is 728 feet, and the width 27 feet: the width of Upper Booth Street, along which it is erected, is 53 feet.

The iron-work was cast and erected by Messrs. Ormerod and Sons, St. George's Foundry, Manchester.

The entire cost of the work, including the foundations, brick-work in cement, ballasting and laying the permanent way, the construction of the new sewer, and repaving the street, was £10,500.

An arrangement was made with the contractor for the iron-work, that a girder of each description should be broken, in order that the actual breaking weight and deflection might be ascertained.

The experiments on the strength of the girders were conducted under the superintendence of, and by means of an apparatus devised for the purpose by, Mr. Eaton Hodgkinson, and as they were made with great care, and in a mode which insured the strain being applied exactly at the centre of the girders, and also for the force and deflection being accurately measured, it may be useful to note the results that were obtained.²

The dimensions of the longitudinal girders were:—

	Feet.	Inches.
Extreme length	28	9
Depth in the centre	2	6·5
Thickness of the vertical web, in the centre		2
Width of the bottom flanch	1	0·1
Thickness of ditto		2
Width of the top flanch		5·1
Thickness of ditto		2·3

¹ It was in this cast-iron screen, or parapet, that Mr. Hawkshaw first observed the results of tight bolting down, in counteracting the usual effects of the contraction and expansion of iron.—*Sec. Inst. C. E.*

² A description of this apparatus is given in Hodgkinson's edition of "Tredgold on Cast-Iron."—*Sec. Inst. C. E.*

In the trial of one of the girders, of these dimensions, the points of support were 27 feet 5 inches apart, and the results of the experiment were as follow :—

Weight in the middle of one Girder.	Equal to a Weight, uniformly distributed over one Girder, of	Deflection in the middle of the Girder.	
Tons.	Tons.	Inches.	
18·4	36·8	·31	
35·2	70·4	·61	
52·0	104·0	·87	
68·8	137·6	1·16	
76·6	153·2	1·29	

This girder broke with a load of 76·6 tons in the centre.

The dimensions of the transverse girders were :—

	Feet.	Inches.
Extreme length	24	6
Depth in the centre	3	0
Thickness of the vertical web in the centre		3·29
Width of the bottom flanch	1	11·9
Thickness of ditto		3·12

The top flanch was dispensed with, for convenience of construction.

In the trial of one of the girders, of these dimensions, the points of support were 23 feet 1 inch apart, and the results of the experiment were as follow :—

Weight in the middle of one Girder.	Equal to a Weight, uniformly distributed over one Girder, of	Deflection in the middle of the Girder.	
Tons.	Tons.	Inches.	
26·8	53·6	·10	
52·0	104·0	·20	
85·6	171·2	·35	
119·2	238·4	·51	
152·8	305·6	·68	

This girder was not broken : the experiment being stopped on account of the apparatus being overstrained.

By calculation (using Mr. Hodgkinson's formula and a co-efficient of 26) the longitudinal girder should have been broken by a load of 58·33 tons in the centre ; whereas, the load by which it was broken was 76·6 tons ; the difference being probable due to the strength of the vertical rib, the dimensions of which exceeded the proportions of girder to which the formula is more especially adapted.

February 10th, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 866. "The Construction and Duration of the Permanent Way of Railways in Europe, and the modifications most suitable to Egypt, India, &c." By WILLIAM BRIDGES ADAMS.¹

IN examining the "Permanent Way" of various kinds, used up to the present period, it is necessary first to settle the exact meaning of the term. In its simple sense, it would imply a way of great durability; but that it does not satisfactorily fulfil this condition, may be assumed from the numerous changes and attempts at improvement it is constantly undergoing.

It must therefore be understood, that the term "permanent way" means some kind of way left by the contractor, when he has removed his temporary way, and which may be of greater, or less, durability, or permanence, according to its structure, but which must, in most cases, be governed by the quality of the material that can be most easily procured. Where timber is plentiful, it is largely used for the substructure; if it is scarce, stone is substituted; and if the capital is restricted, the iron is pinched too closely, as on the early railways, in the United States. Whilst the ballast also varies according to locality, from broken stone, and burnt clay, to sand and gravel.

The principal requirements of "permanent way" are; that it be well drained, and especially in contiguity to the substructure. That the weight and damaging power of the engines and rolling stock, should be considered as the datum for calculation. That the strength, hardness, and tenacity of the rails, and the immobility of the substructure, should be adapted for the hardest work to which the railway is to be subjected. That the substructure should have an amount of bearing surface, proportioned to the load to be borne, and the nature of the soil, or ballast; and a sufficiently firm hold in the ground, to prevent looseness, or lateral movement, from the side lurches of the engines, or trains. That the rails should possess so much vertical and lateral stiffness, either in themselves, or by their fastenings, as to prevent all deflection, and have sufficient hardness of surface not to laminate, or to disintegrate, beneath the

¹ The discussion on this paper extended over a portion of three evenings, but an abstract of the whole is given consecutively.

rolling loads; and have sufficient breadth, or tread-surface, to diminish the effect of the crushing power of the wheels. They should be as smooth as possible on the running surface, to prevent concussion; and be laid at the proper angle, and the curves regularly bent, so as to insure the accurate tread of the wheels: whilst the joints should be so made, that the rails may, practically, become continuous bars, yet with freedom to expand and contract without being too loose. And with all this, there should be interposed, between the rails and the solid ground, some medium, sufficiently elastic to absorb the effect of the blows of the wheels, without being crushed, or forced down into the ballast, and yet stiff enough to keep the upper surface of the rails in a uniform plane.

If these conditions are fulfilled the railway will be a "permanent way" in the full sense of the term.

The ballast may be considered the foundation of the railway; and the depth of it must vary with the structure. If sleepers are used in the ordinary manner, they should be sunk into the ballast, and yet have a sufficient quantity below, to prevent them from gradually sinking. Therefore, the thicker and more efficient the sleeper, the greater must be the depth of the ballast; and this makes the choice of the sleeper an important consideration; which again, is regulated by the kind of rail intended to be used.

The earliest, cheapest, or rather lowest priced and worst form, of wrought-iron rails, is the flat tire-bar rail, spiked down on a longitudinal balk. This was adopted on most of the American railways at the outset, but is now abandoned, on account of the enormous wear and tear, and the great danger to passengers, as the ends curled up, and occasionally killed a passenger, through the bottom of the carriage.

A variation of this kind of way, with the bars edgewise, has been for many years in use in quarries and other places where only a slow motion of the trams is required.

The next in order is the single T fish-bellied rail, ranging from 28 lbs. to 35 lbs. per yard. It was originally patented by Mr. Birkinshaw, in the year 1820, and was first employed to any considerable extent, by Mr. G. Stephenson, on the Liverpool and Manchester Railway (1829-30); but is now no longer manufactured. This rail is a remarkable instance of correct reasoning from unproved data, for though all chair-rails are practically girders, the chairs being the supporting piers, yet in a rail 15 feet long, when the chairs yielded, that reduced portion of the rail which was supported by them, would also yield and bend; so that instead of making the rail a succession of fish-bellies, it ought rather to have been one single

curved line at the bottom, as in the case of the cast-iron fish-bellied rail.

The next is the single **T** parallel rail used with a cast-iron chair : this form, which was first extensively used by Mr. Vignoles, about the year 1833, is a valuable rail, under some special applications, hereafter to be noticed.

The next is the double **I** parallel rail, generally used with chairs : this is a convenient, as well as a very strong mechanical form, and is well adapted for traffic. This double table-rail was first practically adopted on the Grand Junction Railway, by Mr. Locke, M.P., V.P., under whose directions the precise form was carried out by Mr. C. Manby (now Secretary of the Institution of Civil Engineers), to whom the order was given for manufacturing the first quantity, at the Ebbw Vale Ironworks, South Wales, early in the year 1835, when a very elaborate series of investigations was made by Mr. Locke, on the various forms of rails, and chairs, the material for, and the distances between the sleepers, &c. The rail was $4\frac{1}{2}$ inches deep, with a flat bearing-surface of $2\frac{1}{2}$ inches wide on the top and bottom tables, which were precisely similar, and the weight was about 62 lbs. per yard. The chairs were of cast-iron, and were originally intended to have in each a metal filling-in piece, with a round oak trenail, or plug, between it and the face of the jaw of the chair, in order to force it against the web of the rail : this plan was, however, after a very short trial, abandoned, and solid plugs of oak were substituted for the iron filling-in piece and oak trenail. These 'oak plugs, or keys, were compressed into iron moulds, under hydraulic presses, by Mr. Beattie, at the Crown-street works, Liverpool, where, under Mr. Locke's directions, the same process had been in operation for two years previously, and the compressed plugs were first tried on the Liverpool and Manchester Railway.

The foot-rail, a single (reversed) **L** section, with a broad foot, or base, to stand on longitudinal timbers, or on cross sleepers, to which it was bolted down, through holes in the foot, was generally known as the 'Stephenson and Vignoles rail.' It is now commonly used by contractors for a temporary way, with transverse sleepers, to which it is attached by dogs, or spikes, and it was, at one period, extensively used in the United States for permanent way, but being sometimes insufficiently fastened down by spikes, it not unfrequently caused accidents.

Then comes the well-known bridge-rail, first used by Mr. Brunel on the Great Western Railway in 1838, and subsequently, on many other lines.

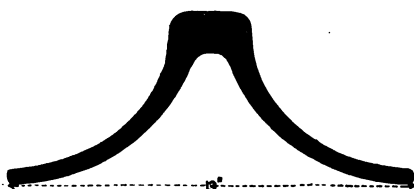
The rail manufactured by Sir John Guest, for Mr. Stevens, C.E.

(U. S. America), is generically a foot-rail, but as it is 7 inches in height, with a foot only $4\frac{1}{4}$ inches in width, and the vertical web only $\frac{1}{4}$ inch in thickness, it is obvious that it must be supported laterally. Probably this is accomplished by bolting it between two longitudinal timber balks, into which the foot is grooved; but the Author has not been able to gain information respecting its real mode of application.

Split rails, or rails rolled in two pieces, both in the form of the half of a double **I**, and also as a foot-rail, with a vertical joint between them, and put together so as to "break joint," are extensively used in America, being manufactured under a patent in England. The object of this form of rail is, in fact, to give a longitudinal scarf through the whole length, so as to prevent bad joints.

Barlow's "saddle-back rail" is the latest great innovation; it is used without sleepers; or, in the words of the patentee, "is a trough rail, bearing on the ballast, and riveted to bearers." (Fig. 1.)

Fig. 1.



Mr. W. H. Barlow's Saddle-back Rail.

Two general systems, known as the transverse and the longitudinal methods, have been adopted, for securing rails upon timber sleepers, and sometimes the two have been combined. But the desirability of adopting a material chemically durable, originally induced the use of stone blocks; and as these have been almost altogether abandoned, it will be well to inquire, why this has taken place, and if for sufficient reasons.

The blocks were usually about 2 feet square, by 1 foot in depth, containing 4 cubic feet of stone. They were of various qualities according to the localities, and were placed, sometimes rectangularly in line, with intervals between them, and at others diagonally, nearly touching at the corners, and forming a continuous foundation, or substructure; in some instances they were laid in ballast, and in others, only in the natural soil.

To insure solidity, which was the object then aimed at, the cast-iron chairs were fitted accurately to the stones, and fastened to them by a pair of iron spikes, each driven into an oak trenail, bedded about

6 inches deep, in a hole bored in the stone block. It was soon found, however, that the chairs worked loose and cut into the stones; and to remedy this, a layer of patent felt, an eighth of an inch in thickness, was placed between the chair and the stone, but the felt being crushed by the heavy weights, the chairs became looser than before. The most probable solution of the defect is this:—the stone blocks partially subsided, irregularly deflecting the rails, which were held down by the spikes, until the elasticity of the rail, in seeking to regain its form, gradually drew the fastenings, and then an incessant hammering ensued between the chair and the stone, on the passage of trains, gradually cutting into the surface of the stone a recess of the form of the chair. To pack the stone blocks, or to restore them to their proper position, at so great a depth, involved a costly operation. Moreover, the noise in travelling was a nuisance to the passengers, and the hardness was found to be very destructive to the rolling stock, and therefore the use of stone blocks was discontinued, and in many cases they were removed from existing lines, and were replaced by transverse timber-sleepers, previously only used in embankments of new construction, being in fact merely “contractors’ way,” but of larger scantling and materials.

Before the question was finally disposed of, an experiment was made on a portion of the Leeds and Manchester line, by levelling the solid rock, in which there could be no subsidence—and fastening the chairs to it, exactly as they had previously been attached to the stone blocks. The result it is said, was, to produce a road so hard and rigid, that it was impossible to continue the use of it, and this was considered to have definitely settled the question. If, however, instead of discarding the stone blocks, they had been used as foundations for supporting the timber sleepers, to which the rails could have been attached, it is probable that a much more really permanent way would have resulted.

The mechanical change that was effected, by the substitution of timber for stone, was comparative freedom from noise, which was undoubtedly an indication of a deflecting rail, rising and falling with the chairs on the blocks.

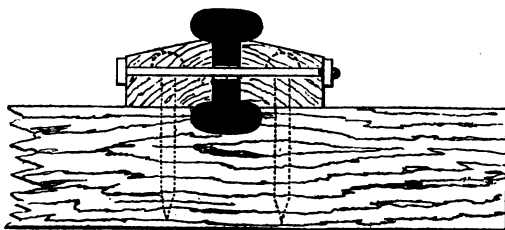
The same rail, transferred to the transverse sleepers, would also rise and fall, but without noise. And that they do deflect is proved by the oozing of watery mud from beneath the sleepers, in wet weather; by the quantity of dust, in dry weather, and by the necessity for continually packing the sleepers, which latter forms a large item in the cost of “maintenance of way.”

Supposing the rails to be integrally strong enough to prevent deflection, when supported at their two ends, the seat of the rail in

the chairs requires to be of sufficient area to prevent that indentation both of rail and chair, which may be occasionally seen to the depth of a quarter, or even three-eighths of an inch.

A simple method of avoiding the use of cast-iron chairs, and at the same time of firmly attaching the rails to the timber sleepers, would be to fasten, by transverse pins to both sides of the vertical web, two short bracket blocks of oak, resting upon the timber sleepers, to which they could be spiked, and supporting the top web of the rail; the bottom web resting upon and being grooved into the sleepers. The inner top of the bracket blocks would not touch the flanches of the wheels. The rails would thus be lower, the leverage would be less, the thickness of ballast would be reduced, the chairs entirely done away with, and considerable economy be effected. (Fig. 2.)

Fig. 2.



Rail without Chairs.

Again, it is essential, that the chair should have such a bearing surface on the timber-sleeper, and be so secured to it, that the side-lurch of the engine, and the springing of the sleeper across the width of the road, cannot disturb it.

The last consideration is, the bearing surface of the sleepers themselves on the ballast. There are generally under each parallel pair of rails, of 15 feet in length, six sleepers of about 9 feet in length, by 10 inches in width, and 5 inches in thickness.

The rail thus becomes a girder-bridge supported on piers, and when the rail deflects, the sleepers are forced into the ballast in detail.

To overcome this depression of the sleepers, either their number must be extended, if needful, till they touch each other, like the corduroy, or plank roads of America, or else the depth and strength of the rails must be increased, so as to prevent all deflection.

In the longitudinal system of timber-sleepers, as used on the Great Western and other lines, with bridge-rails, having a continuous bearing on the timber, the bearing surface of the rails on

the timber is about 6 inches in width, and that of the sleepers on the ballast is about 13 inches. The depth of the rail being about $3\frac{1}{2}$ inches, and the depth of the timber 6 inches.

The quantity of timber used in the transverse system, with four intermediate sleepers to each length of rail, is rather less than 16 cubic feet, and on the longitudinal system it is rather more than 16 cubic feet; or with about the same quantity of timber, the bearing surface on the transverse plan will be about 12 inches in width; and on the longitudinal plan, about 13 inches, giving an advantage of 1 inch in width to each rail, or two inches to the pair of rails, in the longitudinal plan; but as in the latter plan, the sleepers are 1 inch deeper over the whole surface, the effective quantity of timber is nearly 3 cubic feet more. In comparing the expense of the two systems, the cost of the fastening of the rails may be assumed to be equal in both cases, and as the quantity of timber has been shown to be about equal, and the quality ought to be the same, the cost should be alike. For a long period the transverse timber system was considered the cheapest, but the reason was, that on many lines, the sleepers were very small, and of inferior quality, while in the case of the longitudinal system, it was essential always to have good timber. In addition to the increase of bearing surface in the longitudinal system, the broad base of the bridge-rail makes it much stiffer laterally, than the double **I** rail, and its smaller depth offers less opportunity of accident, from sudden lurches of the engine. But, on the other hand, the bridge-rail being only $3\frac{1}{2}$ inches in depth, is liable to deflect under loads, by which the double **I** rail, 5 inches in depth, would not be affected.

Though the longitudinal timber tends to stiffen the bridge-rail vertically, the real effect depends entirely on the fastenings. The rail has two lateral flanches about $1\frac{1}{2}$ inch wide by $\frac{1}{2}$ inch in thickness, through which holes are pierced at intervals of 3 feet.

In the earlier examples these rails were fastened down by screws; but as the rails and the timber deflected, a sliding movement took place between them, similar to that between the plates of a carriage-spring; the screws were loosened, drawn out, or broken, and the timber was crushed in detail. To remedy this, in some cases, the timber was cross-boarded, with manifest advantage, and in most cases bolts with nuts passing through the rail-flanches and the timber, were substituted for the screw-bolts; subsequently, plates were introduced under the rail-ends, and also below the timber, and the bolts passed through all. But the author is not aware of any fastening yet being found quite effectual in preventing deflection, or the

working movement between the rails, and the timbers, or the loosening of the bolt-heads.

On the old Croydon line, where the longitudinal system was used, with very light bridge-rails, it was not uncommon to find rails broken into two, or more lengths, by constant deflection, and they were repaired by placing a plate beneath the fractured ends.

With regard to the cost of repairs, the mere packing of the sleepers, under equal weights, should be less in the longitudinal system, because there is more bearing surface; but to set against that, the wood is more crushed than in the transverse system with chairs, and the access to the bolts is very troublesome, while the fastening of the double **I** rails in the chairs, by wooden keys, is very simple, though in the joint chair, it is insecure, and the rising of the ends is a common cause of accident. The author, therefore, in the year 1848, suggested a new variation, combining the use of the double **I** rail with the longitudinal sleeper, so as to avoid deflection and to obtain the continuous bearing. Dividing the half balk of timber, about 7 inches by 14 inches, into two parts, the double **I** rail was half-grooved into each, and bolts being passed through, below the rail, it was held as in a continuous wooden vice, embedded to the upper lip, the flanche of the engine-wheels being cleared by a shallow groove. Four lengths of this were laid down on the Eastern Counties' line, where it appeared to answer well, and is still in good order.

With respect to the durability of timber-sleepers there appears to be some difference of opinion, arising, probably, from the various descriptions of timber employed. There have been two principal systems employed, for rendering timber artificially durable. The one was by saturation with certain chemical solutions, or mineral salts, which act chiefly on the albumen, producing a kind of tanning effect, but by which the mechanical strength of the timber is stated to be impaired; moreover the salt being soluble in water, is apt to be washed out again. The other system, now very generally employed, is by 'creosoting,' or injecting coal-oil, under pressure, by which both mechanical toughness and chemical durability are produced.

Engineers have recently shown a disposition to resort to other materials, and it has been considered, whether it would not be possible to employ stone, which is chemically and mechanically the most durable material, and would afford a perfect foundation, provided the rails could be properly attached to the blocks.

If the thickness of these blocks was reduced from 12 inches to 6 inches, the superficies remaining the same, and they were laid

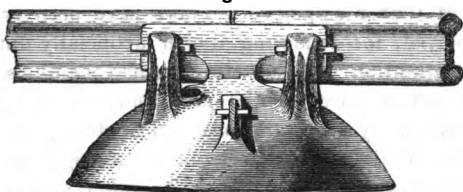
beneath each line of rails, nearly touching each other, and so as to support longitudinal sleepers, 8 inches by 6 inches deep, with bridge-rails, bolted down between every joint of the stones, through rails and timber to a small block below, a continuous bearing would be formed of chemically-durable sleepers, equal to 60 feet of surface beneath two rails, whilst a sufficient amount of elasticity would be given. At the same time it is probable, that no other ballast would be required, as the extended bearing surface would prevent displacement, and a true permanent way, when once settled and undisturbed by the rolling loads, would thus be formed.

Of course, the question of the cost of stone must depend chiefly on locality. In some districts it might be desirable to use cast-iron, or slate-flags, or the slag of the iron furnaces might be run into moulds. On this plan any kind of rail might be used; for instance, a deep foot-rail, with a half-foot angle-plate, bolted laterally to its break-joint, to save timber, or a girder-rail between timbers, or probably the double **I** rail bedded between two timbers, as before described.

The objections to the use of timber-sleepers, rendered very prominent by the inferior wood used in transverse structures, induced Mr. Reynolds, in 1836, to propose inverted troughs of cast-iron, lined with wood.¹

Subsequently, in 1846, Mr. Greaves, of Manchester, introduced a new metal sleeper, possessing several useful properties. (Figs. 3, 4, and 5.) This sleeper is a semi-spheroidal bowl of cast-iron,

Fig. 3.



Greaves' and Douglas' fish-joint Chair and Sleeper.

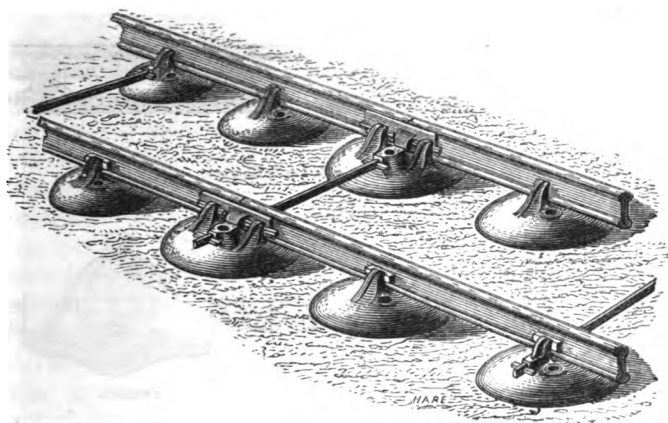
Fig. 4.



Greaves' surface-packed Sleepers, with Douglas' fish-joint Chairs.

¹ Vide Trans. Inst. C.E., vol. ii., 1838, page 73.

Fig. 5.



Greaves' surface-packed Sleepers.

having the chair, of any form, cast upon its apex, and is connected firmly with the opposite sleeper, at intervals, by a transverse bar, which preserves the gauge and retains the travelling table of the rail at the proper angle. The joint sleeper has Douglas' fish chair applied to it; this is a double-headed chair, with loose fishing plates of cast, or wrought iron, attached to the rails by split iron keys.

There are several advantages in this system; the form of the sleeper is strong,—it holds well in the ground;—the chair is not liable to be detached,—the whole bearing surface is directly beneath the load,—the ballast is always kept dry and elastic,—and there is an extremely ingenious contrivance for packing it through two holes, with a pointed rammer, from the surface, so that the sleeper and rail can be forced upwards, without disturbing the general bed of ballast, or they may be lowered by taking out a portion from the interior. The danger of admitting water, by opening the ground, is thus obviated, and in certain situations this is of great importance. The sleepers are in use on several lines in Great Britain, on the Continent, and in the Colonies, and Mr. Robert Stephenson, M.P., V.P., has adopted them for the Egyptian Railway.

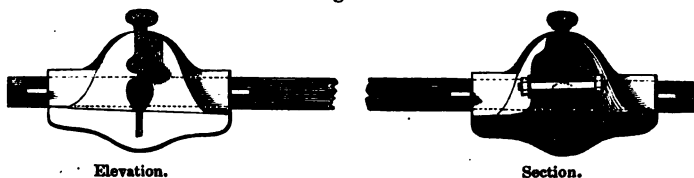
The next kind of cast-iron sleeper was that introduced by Mr. Peter W. Barlow, M. Inst. C. E., in the year 1849, on the South Eastern Railway. (Figs. 6 and 7.) Each sleeper is in two pieces, and consists of a plate 3 feet long by 7 inches wide, with two half-chair heads cast upon it, except that for the joint-chair, which has

Fig. 6.



Mr. P. W. Barlow's Cast-iron Sleepers.

Fig. 7.



Elevation.

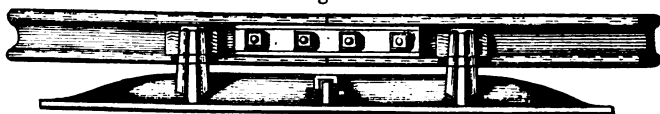
Section.

three half-chair heads on it; these are made to grip the lower-half of the rail tightly, by means of screw-bolts, passing through the chair-heads below the rails, and holding them as in a vice. The casting of these plates so as to fit the rail perfectly, and to preserve all the metal in a state of rest, is a work of some nicety.

Another cast-iron sleeper was brought forward by Mr. William H. Barlow, M. Inst. C. E. : it was very similar to the former, except that it was cast in one piece, the rails being fixed in the chairs by keys, in the usual manner, or by resting the rail on a wooden block, keyed in below it.¹

¹ These sleepers are in use, and are much approved, on the Londonderry and Enniskillen and Londonderry and Coleraine Railways; and since the paper was read Mr. W. H. Barlow has adopted, with excellent results, on the Midland Railway, a form of cast-iron sleeper, combining the best properties of Mr. P. W. Barlow's sleeper, with the suspended fish-joint. *Sec. Inst. C. E.* (Figs. 8 and 9.)

Fig. 8.



Mr. W. H. Barlow's Cast-iron fish-joint Sleeper, as used on the Midland Railway.

Fig. 9.



Elevation.

In both these plans, it is evident, that the rail must be sufficiently stiff in itself, to prevent deflection, as the sleepers are not continuous. Mechanically considered, the latter plan appears the best, as the wood-keys can yield slightly and equalize the deflection of the rail, whereas, any bending of the rail, in the other plan, would be apt to break the sleepers.

The cast-iron sleeper introduced by Mr. Samuel, M. Inst. C. E., is a wedge-shaped trough, deep enough to take the total depth of the rail, with two inclined side wings, at the upper part, to bear on the ballast. The rail is grooved into two pieces of timber, which clip it at the bottom and the sides, and being forced into the trough, the wood is compressed. The troughs are, however, not continuous bearings, and therefore the rail must be strong enough not to deflect.

This is, mechanically, the best arrangement of the cast-iron sleepers hitherto examined; but as it is evident, that the retention of the rail in the timber cushion depends on the tenacity of the cast-iron trough, it must be made very strong, to prevent the wedging action from splitting it across the bottom. It is, however, a defective arrangement to make the bearing wings pitch downwards, as it induces unsteadiness; they should rather have been reversed, if not made horizontal.

The cast-iron sleeper, introduced by Mr. Hoby, like the sleeper of Mr. Samuel, is a trough, though of a different shape, the internal section being that of a prolonged chair, into which folding wedges are driven laterally, to secure the rail in its place. The side-bearing wings are pitched downwards, and the sleepers are not continuous. The rail fits in the bottom of the iron trough, and also against one side, and it will require very nice moulding and rolling to secure an accurate fit, but the elastic wood wedges will reduce the chance of fracture.

Another variety is an imported French sleeper, consisting of an ordinary chair, cast solid on a plate of 18 inches square, and merely resting on the surface of the ballast.

Another variety of sleeper is that of Major Cochrane. It is a flat cast-iron plate, with a pair of ribs upon it, forming a channel about two inches square, filled with timber, on which a flat-bottomed rail is held down by wedges, driven into projecting chair-heads, in the usual manner: it is evident, that if the rail deflects, the timber must be crushed, as it presents a very small bearing surface, and a rail with sufficient depth would possess a very unsteady base, unless the sleepers were cast in the form of a trough.

Cast-iron may be used, efficiently, for railway sleepers, but the masses must be larger than have hitherto been applied, and the form must be continuous; or if detached, the sleepers should only serve as piers, or points of support, in which case the rail must be non-deflecting.

Having examined the different kinds of sleepers, with reference to the vertical and lateral support they afford to the rails, the next question is that of the various modes of attaching the rails to the sleepers, in order to prevent the jolting and unsteadiness usually experienced on ordinary railways.

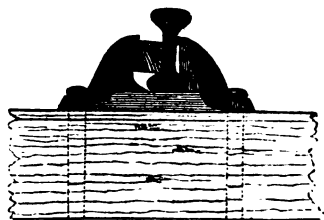
About the year 1832, or 1833, a reward of £100 sterling was offered by a railway company, for the best mode of securing rails to chairs. Many plans were sent in, but none were integrally adopted. It was said, that an amalgamation was effected between three of the competitors, and the reward was divided.

The fastening so rewarded was not successful, and it was soon found, that the wooden key was the only arrangement that did not rapidly get loose. Many of these, however, were too small; the rails were loosened laterally, and a creeping motion was induced by the action of the breaks on the wheels, not unfrequently causing accidents.

The mode of fastening the chairs to the sleepers, by means of iron spikes was insufficient. Rust got in between; the two irons were then rapidly worn away, and all became loose. This gave rise to the improved chairs of Messrs. Ransomes and May, hardened in chills to prevent the rails from crushing them, but not preventing them from crushing the rails, and with large-sized compressed trenails of oak, to attach them to the sleepers. (Figs. 10, 11, 12, 13, 14, 15, and 16.)¹

Fig. 10.

Ransomes and May's Chairs and compressed Wedges and Trenails.

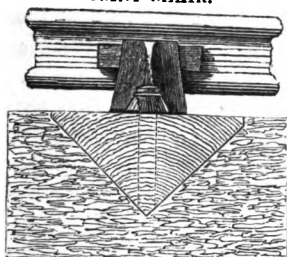


Elevation of Chair, showing the inclination of the Rail.

¹ Vide Minutes of Proceedings Inst. C. E., 1842, vol. ii. page 72.

Fig. 11.

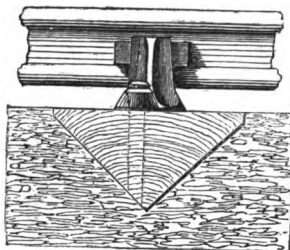
JOINT CHAIR.



End View.

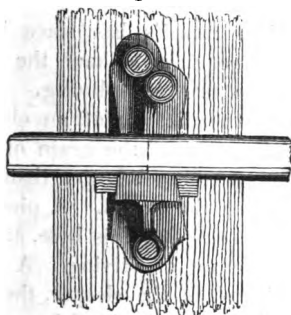
Fig. 13.

INTERMEDIATE CHAIR.



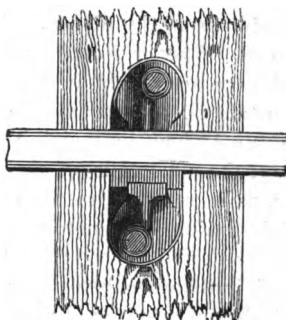
End View.

Fig. 12.



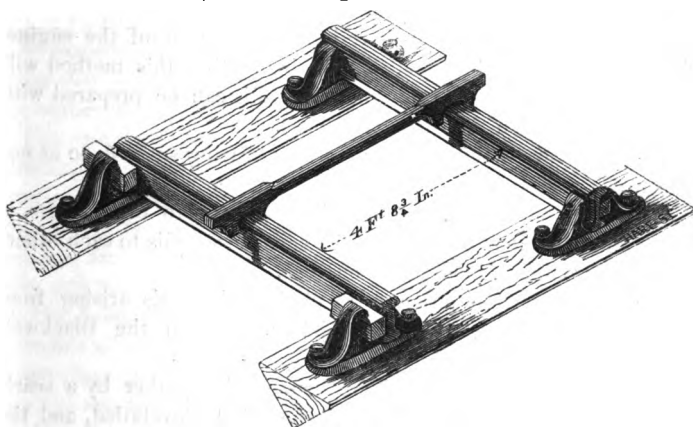
Plan.

Fig. 14.



Plan.

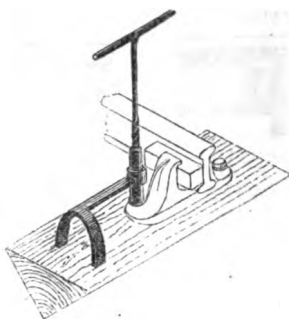
Fig. 15.



Rails, Chairs, and Sleepers, with the 'cramp-gauge' fixed.

[1851-52.]

Fig. 16.



Guide-tube and Auger.

A simple mode of preparing oaken trenails has since been proposed. The ordinary round trenail requires to have the hole bored very accurately in the sleeper, to prevent splitting. The new mode is, to cast in the chair a trenail hole of an oblong form, say $1\frac{1}{4}$ inch by 2 inches in the direction of the grain of the sleeper, the upper side of the hole being as much larger than the lower, as is required to form the head of the trenail. A piece of straight-grained oak, not over dry, is driven into this hole, and is compressed, and the sap forced out in the act of driving. A hole $1\frac{1}{4}$ inch in diameter being previously bored in the sleeper, the trenail is driven into it, and cannot split it, because it is of less width than the hole across the grain. But it drives very forcibly in the direction of the grain, precisely in the mode of a chisel-shaped brad, which forms its own hole without splitting, and it offers the greatest amount of resistance in the direction of the lurch of the engine. If chairs continue to be used, it is probable that this method will be found advantageous, as the square trenails can be prepared with greater facility than the cylindrical ones.

The wood keys should also have ample bearing surface, so as not to be crushed with the side-lurch of the engine.

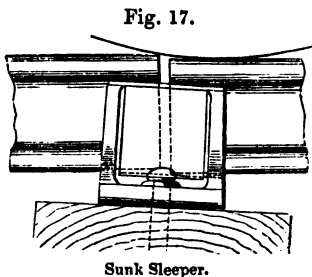
Apart from the question of securing the rails to the sleepers, is that of the best mode of securing the ends of the rails to each other, so as to approximate to a continuous bar.

One of the earliest attempts to obviate the evils arising from insufficient connexion at the rail-joints, was on the Blackwall Railway.

In that case the rail-ends were connected together by a scarf-joint, about 6 inches in length, with the points dovetailed, and the whole wedged into the chair. As these rails were only used with

rope-traction, and were not tested by locomotive work, for which they were not intended, no deduction can be drawn from them; but they were weakened by the scarf, and were expensive in manufacture.

On examining the joints of a railway out of order, it will be found, that the forward end of each rail, in the direction of the traffic, stands, apparently, slightly higher than the hinder end of the rail in front of it (Fig. 17). When the weight comes on it, so as to press it down to the chair, it becomes the lowest, as the under part has been hammered in the chair, and the rail is reduced in depth. When once rails are thus hammered, it becomes impracticable to secure them firmly in the chairs, except by cutting off their ends.



Sunk Sleeper.

The joints of the rails are evidently the weakest parts of the line of way; therefore the great object is how to strengthen them; and this cannot be done by taking away metal from the already too weak part. Supporting the joint by extra sleepers appears a simple remedy, but the sleepers are not practically supports, as they only bear on loose ballast, and not on any continuous surface. It becomes necessary, then, to join the rails firmly together. The operation of 'fishing,' by the addition of pieces of metal to each side, then presents itself; but to secure these 'fishes,' becomes the next question. The simplest mode is to take the rail-joint wholly out of the chair, and to place a sleeper, with a chair on it, on each side of the joint, thus suspending the joint between the two chairs. The 'fishes' being then driven in on each side of the rails, the rails and chairs are connected together. This was practised by the Author in 1847.

The damaged rails were thus supported by the chairs in the undamaged part, and they were made practically continuous, while permitting expansion and contraction, by the sliding of the fishes. But putting the fishes into the chairs involved the necessity for fresh castings, and it was found a simpler operation to punch holes in the rails, and connect the fishes together by four bolts passing through all, the holes in the rails being larger than the holes in the fishes, to permit of expansion and contraction. The first fishes tried were of cast-iron, and they answered very well; but subsequently wrought-iron was substituted, the edges of the fishes bearing against the top and bottom of the web of the rail, leaving the middle untouched, so that the bolts were held as it were in spring tension endways, and

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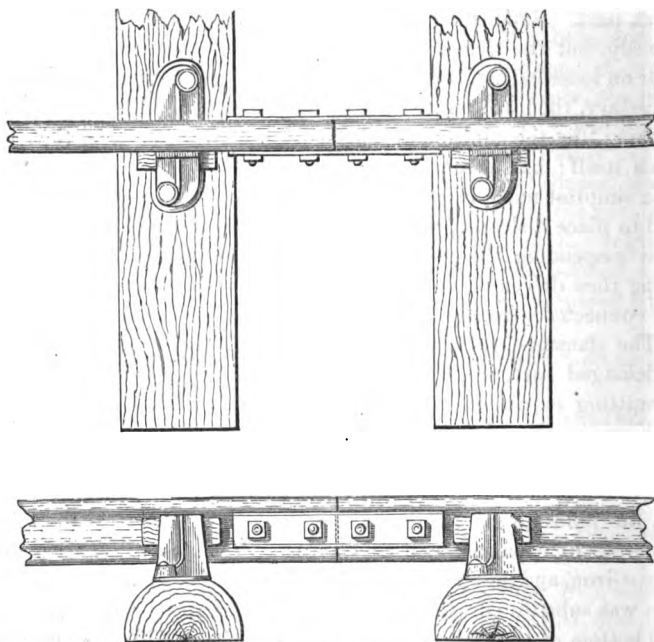
therefore did not work loose. So perfect was this arrangement, that old rails, which had become useless, when battered at the ends, so that one end projected nearly a quarter of an inch above the other, when once firmly connected by the fishes, gradually rolled, under the working of the trains, to a perfectly level surface.

This plan did not, however, get into general use, and the Author having many other subjects to occupy him, the matter lay in abeyance, but some experienced engineers, convinced of the efficiency of the system, became possessed of a portion of his interest in it, and have since been enabled to extend its adoption, with good practical effect, entirely confirming the soundness of the original views relative to it.

The application of the 'fishing-plates' to ordinary rails is very simply and rapidly effected, and the results are very satisfactory (Figs. 18 and 19).

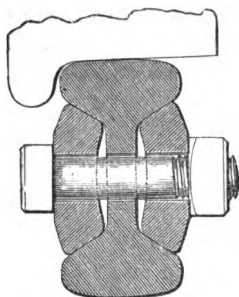
The next proposition for improving joints was by Professor Gordon. It was, to make a horizontal lap, by cutting away 3 inches from the top of one rail, and 3 inches from the bottom of its neighbour, to half the depth of each, and then lapping them together

Fig. 18.



Fishing-plates applied to ordinary Rails.

Fig. 19.



Enlarged Section of Rail and fishing-plates.

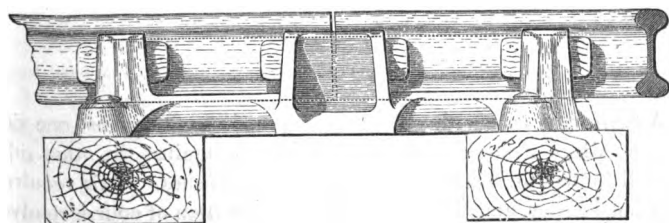
and securing them in the chair. It was expected that the hinder rail in the line of progress, thus lapping over the forward one, would keep both down together. But whether from bad iron, or from the diminished strength of the parts, it was found that the ends broke off, and the plan was abandoned.

At length, in the year 1849, the authorities on the Eastern Counties Railway resolved to try the experiment of the 'fish-joint.' Some half-dozen rails were jointed with cast-iron fishes, and they were found to answer.

Many persons went to examine them, yet though all appeared satisfied, the railway companies and the engineers exercised a wise discretion in waiting till experiment had become experience. Progress under such circumstances is slow, and, moreover, as the trial seemed to throw a new light on the question of good joints, many new experiments were made.

Mr. J. Fowler, M. Inst. C. E., produced a chair-joint, (Fig. 20,) formed of three pairs of jaws cast together upon a sole-plate, the two extremities resting upon two sleepers below: it is said to answer well on the East Lincolnshire line, and has been in use there since 1849. Various other plans also were tried, or suggested.

Fig. 20.

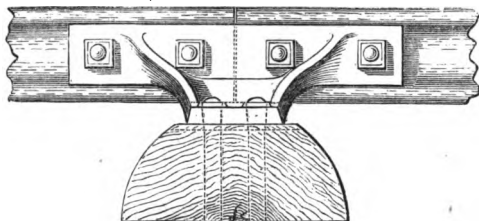


Fowler's Joint Chair.

In applying the fish-joint to the repair of rails on lines, when funds had grown scarce, an objection arose to the cost of an extra sleeper and chair, in addition to the fishes. To meet this objection, Mr. Samuel contrived a modification of the 'fish.' (Figs. 21, 22, and 23.)

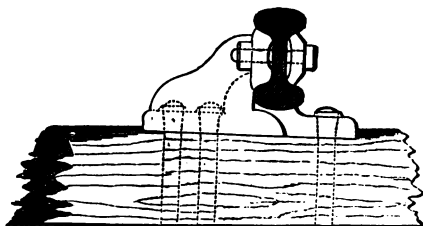
Fig. 21.

SAMUEL'S FISH CHAIR.



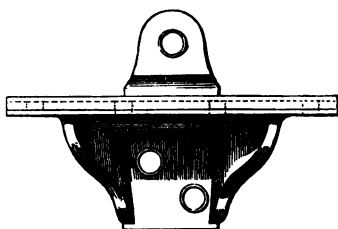
Side View.

Fig. 22.



Section.

Fig. 23.



Plan.

A chair was cast with only one jaw, made to fit against one side of the rails, a wrought-iron fish being placed against the other side, and all bolted together through the rails and fishes. This required only one sleeper, and the value of the modification of course resolves itself into a question of bearing surface on the ballast. If one

sleeper be sufficient there is no use for two, but it would be an unwise economy to save sleepers and to expend more than the amount in maintenance of way.

In the original specification of the fishing plan, it was foreseen, that many evasions might be resorted to, and various modes of accomplishing the same object were suggested and shown. Double-headed chairs were specified, and also the mode of casting the chair-heads to fill the channels of the rails. A plan of splicing rails was also provided for. It was to roll the rail double, with a vertical joint from top to bottom, and to fix them together 'break-joint,' i. e., with the joints of one pair of half rails, abutting on the solid portion of another half rail, so that the rail would practically be continuous, the rails being riveted, or bolted, or fished together laterally. It will of course require more iron to construct rails on this plan, than in the solid form; but, though hitherto unused in England, the system has been rather extensively used in the United States and in the colonies, and is frequently preferred to other arrangements, the rail being very quiet, the absence of solidity preventing any ringing noise.

An unwise economy has generally been practised, in restricting the quantities of Railway material, or fixed plant, though there has been no such economy in rolling stock. At the outset of railways, iron was the most costly commodity, and all methods were sought to lessen its consumption. This idea was continued as a kind of superstition, long after iron became cheaper, so that at the outset of the Author's experiments, he found, that to increase the weight of the permanent way was considered a kind of misdemeanour, to be avoided by any means, and a second chair to a joint was held to be a great extravagance, yet almost immediately on the production of the fish-joint, iron seemed to increase in quantity, and its cost to lessen in many ways. The quantity of cast-iron sleepers used on the South Eastern and the Midland Railways, appeared to have overthrown the superstition, and timber was suddenly pronounced to be wholly unfitted to be classed amongst the materials of permanent way.

Occasional breakages of cast-iron sleepers, owing to the desire to lessen the first cost of material, and thus unduly reducing its proportions, caused attention to be turned to the capabilities of wrought-iron.

The saddle-back rail of Mr. W. H. Barlow, previously alluded to, (page 247, Fig. 1,) was the first result. This rail is usually 13 inches in width, and $5\frac{1}{4}$ inches deep, and weighs 126 lbs. to the yard.¹ It

¹ The weight now generally used is 90 lbs. to 94 lbs. per yard.—*Sec. Inst. C. E.*

is stated, that "it will bear a pressure of 40 tons without spreading out in width, and of 27 tons between bearings, 4 feet 4 inches apart, without its elasticity being injured; the stiffness of the rail virtually increases its bearing surface, for if a weight be placed over the centre sleeper of a length, and the rail be flexible, the whole of that weight will be borne by the sleeper, whereas, if the rail be rigid, the weight will be equally distributed over the adjoining sleepers."

If this rail be as rigid as it is described to be, with a proper extent of bearing surface, and is sufficiently heavy to remain quiescent under the rolling loads, there ought to be no cost of "maintenance of way," but only the expense of renewal from time to time. But upon examination it appears, that though the rail is 13 inches wide, this is not all true bearing surface. If the trough, or hollow, were filled with adhesive ballast, that could not leave it, the whole width would be bearing surface, but it appears to lie on the ballast as a saddle lies on a horse's back. It is stated, that considerable noise is experienced in running over this rail. If so, this would indicate a hollowness. In dry sandy ballast, however well the hollow of the rail might be packed, it must always be falling away from the upper part of the trough. Then again, the side surface to resist displacement, by the lurch of the engine, is but 4 inches, in a wedge form, tapering down to a sharp edge, like the form of a ploughshare. This want of hold must render the process of packing very difficult.

It is stated, that "in this wrought-iron rail, there is a sensation of hardness, which appears to result from the rails having been laid down a short time, and not having been worn to sufficient evenness on the upper surface." There can be no doubt, that the mere roughness, from the rolls, on the surface of rails, is sufficient to produce positive blows at high speeds, and were it practicable to produce a smooth surface on them, there would be a great advantage in it, not merely by the even face, but by hardening. But assuming the saddle-back rail to be a rigid girder, another consideration ensues. It is stated, by experimenters, that the limit of weight which can be borne by the best wrought-iron, before it begins to be crushed, is 11 tons to the square inch. Rail-iron has been stated to be only equivalent to 8 tons per square inch. But the impact of a driving-wheel with 7 tons weight on it, is only a point, and under favourable circumstances a line, unless the rail deflects and partly laps round the wheels. If this be correct, it follows, that a rail ought to laminate and roll out under heavy engines, as has actually occurred in many instances. Though it must be stated, on the

other side, that there are many rails which have been down for years under heavy engines, and are still not injured, probably escaping lamination by elastic deflection.

If it be resolved to continue the use of inflexible girder rails, one of two methods must be resorted to. The first is, to make the rail of steel, or to steel the surfaces, and the other is, to increase the width. As the weight on the engine is greater than that on the train carriages, or waggons, it might be desirable to construct the rails with two surfaces, the double surface for the engines, and the single surface for the train, with a channel rolled between the two for the holding down bolts, which will be presently alluded to.

Reasoning on the absolute necessity, in regard to economy of maintenance of way, of obtaining an inflexible rail, that will not crush either the ballast, or the sleepers in detail, the question changes, from Mr. Barlow's rail to his mode of connecting his rail-ends together, for if the connexion does not produce equal strength with the other portions of the rail, mischievous results ought to ensue, unless the middle of the rail be three times the breaking, or deflecting strength, and the joint only twice, and then there is a waste of one-third of the strength of the rail.

The mode used is, to place below the two rail-ends a saddle of wrought-iron, about 2 feet in length fitting the trough. To this saddle the two rail-ends are riveted firmly at the outer edges, without any provision for expansion, or contraction. The upper portions of the rails abut closely together, and thus the lower part is in tension, and the upper part in compression, and the two together form a beam, the strength of which must depend on the power of the rivets to resist being sheared off.

Supposing the upper, or abutting portion to be removed, the lower portion with the rivets would be apt to bend under a load, consequently the strength of the joint must depend on the abutting ends and the strength of the rivets. If, therefore, there be any expansion, the rails must elongate through the whole length, and slide over the surface, or they will buckle upwards, or sideways. But it is said there is no expansion; and if so, it is possible that the contact of the earth carries off the heat as it is generated, just as water carries off the heat applied to the bottom of a boiler.

It would appear clear, that when the upper portion of this rail is worn by the traffic, a very large quantity of iron will have to be removed, and renewed. This of course is a matter for commercial consideration on one side, and of mechanical convenience on the other.

Assuming that, for certain purposes, the solid rail might be

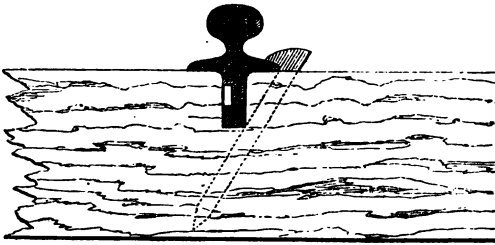
desirable, it remains to be proved that the saddle-back is the best form, either for strength, or for packing. Lateral and vertical stiffness, with large bearing surface vertically, and security against lateral shifting, are the objects sought for; and with these points in view, the T form section, with the rail, or rib, on the upper surface, appears to be well adapted for general use. In this form there is a bearing surface horizontally of 14 inches in width, the total depth is 9 inches, and the depth below the horizontal surface is $6\frac{1}{2}$ inches, giving great vertical stiffness, and serving as a keel to prevent lateral movement in the ground, the rail being used without any sleepers. To form the joints, two cheek-plates, about 2 feet in length, might be bolted to the vertical and horizontal portion, with allowance for expansion and contraction in the holes through the rails, which are made larger than in the cheek-plates. This rail would lie very firmly in the ballast, and the packing from the surface would be very easy, the vertical web forming a solid back to ram the ballast against. If it were required to key more firmly in the ground, a timber might be bolted to the lower edge. It might be objected that there would be a difficulty in rolling this rail, but practice decreases those objections daily; in fact, there is, practically, no mechanical difficulty to large demands. It might be objected to this rail that it might be noisy, but probably it would be less so than a trough-form rail.

If a quiet rail be required, without vertical deflection, it may be produced by rolling an upper table with a deep thin vertical web, and bolting it laterally between two timbers. To secure adhesion between the timbers, the sides may be rolled to the form of the planking of a clincher-built ship, multiplying in that mode horizontal bearing surface on the timber, or a T-formed rail may be used.

A webbed girder-rail may be used with transverse sleepers, without chairs, by adding to a foot-rail, a deep web, to be inserted to the depth of 3 inches in the sleepers, so that the feet rest horizontally on the surface of the timber and are fastened down by dog-head spikes. At the joints the rails might be attached together by plates fitting into a longitudinal groove rolled in the web (fig. 24). This rail, whose upper table would be only $2\frac{1}{4}$ inches above the surface of the sleepers, would possess great vertical and horizontal stiffness, and would be a cheap and serviceable form of railway.

Solid rails, such as have been described, might be difficult to bend for curved lines, on account of their width; but by making a girder rail of several pieces, the difficulty may be overcome. A flat plate 14 inches wide may be bolted between a bridge, or foot-rail, at the top, on a T-girder below, the bolt-holes in the flat plate being disposed in the curved line required, and the rail and T-girder bent to

Fig. 24.



Webbed-foot Rail.

it. To make the joints, cheek-plates may be bolted laterally to the girder, and the rail break-joint with it. The bolts require to be strong, to make the girders firm.

Another variety of girder-rail is formed by a bridge, or foot-rail, bolted on two wide and deep angle-plates which break-joint with each other and with the rail, and thus no cheek-plate is required at the joints. This rail would be quiet, the division of parts preventing ringing. Many other varieties of form have been devised for particular localities.

The question of adhesion must be viewed from two different aspects. In driving-wheels, the maximum of adhesion, up to the propelling power, is required. In all other wheels adhesion should be got rid of altogether. The Author is not aware, that any experiments have been made, to ascertain whether the conical form of the periphery of the driving-wheels assists, or retards propulsion; but it is clear, that if a conical-formed tire presses over the whole width of the rail, with equal intensity, there must be a universal grinding action, which, even supposing it to be beneficial in the case of the driving-wheels, must be mischievous in all other cases. Therefore it is clear, that steel rails and cylindrical peripheries are mechanically desirable, in one point of view, for all bearing-wheels, unless other circumstances intervene, which render the friction a lesser evil in comparison with something else. That a considerable friction does take place, involving the rubbing of tires on rails, may be judged by the fact, that the rails in use, present a burnished appearance, and that after the passage of a train particles of metal resembling black-lead dust are found on the rail surface.

Experiments to determine this question of friction and adhesion on firm inflexible rails of iron and steel, and with conical and cylindrical wheels, are much wanted, and would prove valuable data for railway companies, involving as they do the question of diminution of cost of haulage and of maintenance of way.

There is another subject, in railway maintenance, which appears to have been overlooked. Provision has been made for drainage, but not for drainage in immediate contact with the rail. It is known by experience, that the vibration of passing trains commonly opens a thinner, or thicker air-space, between the vertical edges of the sleepers and the ballast, when the weather is dry, and that into these portions of the way rain finds its way as to a drain. The sleeper being absolutely loose from all lateral adhesion, springs up and down beneath the trains, and packing is required. The oozing of the fine washed sand from the sides of the sleepers points this out to the way-men. Moreover, even in continuous rainy weather, the ballast being an absorbent material, or sponge, and the sleeper non-absorbent, the greater mass of water will be found at the point of contact, precisely as the water of gravel-beds is intercepted by a clay stratum.

Impressed with this defect, the Author was led to consider the practicability of getting the drains close to the sleeper, and the most obvious mode was, to make the sleeper itself the drain, by constructing it of perforated iron, or supposing iron rails to be used without sleepers, to make the rail itself the sleeper. The plan proposed to accomplish this is to roll a rail with a deep thin vertical web; two angle-pieces of cast, or of sheet iron, bent to the requisite form are bolted to the rail above and below, breaking-joint; these angle-plates are perforated, and the water will find its way through the perforations, precisely as it does in ordinary clay drain-pipes, and may be led away to the exterior at convenient intervals. The form of this rail will give perfect rigidity; and if perfect rigidity be compatible with durability of the running surface—a point not yet satisfactorily made out—and if the bearing surface be in excess of the load to disturb it, it ought not to require any maintenance of way. In using the term rigidity, it must not be understood as applying to a torsive strain, such as an engine flanch would tend to produce, as it would have a slight elastic yielding in that direction. The packing of this kind of rail would be exposed to the same difficulties as ordinary longitudinal, or transverse sleepers, from the depth of bearing below the surface; but this might be obviated by reversing the angle, and placing the flat above, as in the triangular sleepers of the Dover line. Or the two sides might be curvilinear, for the purpose of inducing more stability, and preventing rocking on the ballast.

A copious use of water would do away with the annoyance of dust, and be economical for maintenance of way.

Supposing a rigid rail to be impracticable, on account of lamina-

tion, it will become necessary to devise a mode of producing yielding, or vibration of the upper surface, without in any way disturbing the portion which rests on the ballast. For this purpose, the Author would propose to use a rail with a deep thin vertical web, bolted so as to break-joint, between two angle-plates at the upper portion, as before described, but with a space between the bottom of the rail and the bottom bearer. If the rail deflects, it must, on account of its great depth and fastenings, deflect only on a considerable length, and that without disturbing the bottom. If the pressure be excessive, it will take a bearing on the bottom and will in fact be a spring-rail. The bottom may be of cast-iron, but in all cases it will be sufficiently solid to prevent its yielding in the central part.

The girder-rails, or sleepers, thus described, are in common with the trough-rail subject to a defect. They are mostly of wrought-iron and therefore liable to oxidate. If this be a serious objection, it may be remedied by a coating of zinc, or other metal, or by bituminizing, or covering with mineral paint, or coal-tar.

How far such a principle of rail might be available as a pipe for the transit of water, for other purposes than watering the road, is a matter for consideration.

In the American Union the railways run through the streets of towns. It has hitherto been found difficult to construct a line of this kind, so as to bear the rough usage of carts and waggons that run over the rails in every direction. Some of these lines are constructed of heavy cast-iron, and cost as much as 24,000 dollars per mile, equivalent to nearly £5,000. It would appear probable, that solid girder-rails of wrought-iron, such as have been before described, would be found to answer the purpose.

With regard to the applications of "permanent way" on the Continent, two patterns appear to have been set. One, the American pattern of the foot-rail and longitudinal balk, fastened by dogs, which prevails very commonly in Germany; the other, the English double T rail and chair with transverse sleepers. In France, the English system is the general type. But the American system has scarcely been used in England, save by contractors, for temporary work. It has, however, been stated, that longitudinal timber sleepers on stone foundations, have been found to form the most really permanent way of any used in the United States, where "maintenance," on account of the high price of labour, is a very costly item.

In speaking both of the longitudinal and transverse sleepers, the combined systems, partially introduced, have not been alluded to. In truth, the rail being rendered non-deflecting, the other consider-

ation is, how can it best be secured to a sufficient mass of bearing surface on the ballast, to secure it against sinking? With a non-deflecting rail, it is a matter of no consequence, whether the bearing surface be equally distributed, or be placed upon sleepers, like piers, save that, the farther the bearings are apart, the stronger and heavier must be the rail and the sleeper, or pier foundations.

In discussing the durability of way, the question of constructing the levels and the inclines, forms an important item.

Supposing a line to be required to be worked by fast, or express trains, not stopping, and by a number of other trains, stopping at very frequent stations, the plan is occasionally resorted to, of making sidings from the main-line, at the stations, in which the stopping trains may pull up, while the express trains may run by unimpeded.

In starting the trains from the stations, great surplus power is required, and in arriving, great damage is done by the friction of the stopped wheels on the rails. But if it were practicable so to arrange it, that the main line might be on the level, while the sidings, or stopping stations, were on an elevation, less engine-power would suffice to start and to work the trains, and no break-power would be required to stop them. The artificial levels might easily be arranged, by constructing the stations on brick arches alongside the main line, and letting the siding road run over the arches, which would form summit levels, the offices being below. And by a proper disposition of rails on elastic timber, the vibration might be sufficiently diminished, bearing in mind also that no rapid movement would exist on the immediate summit.

The question of permanent way in Egypt, India, &c., involves some new considerations. Railways, in themselves evidences of a high state of civilization, are unquestionably, calculated to become the most effective implements for bringing semi-barbarous countries into a state of civilization. But as railways, in such countries, must pass through wild districts, thinly peopled, where fences and police cannot be maintained, and where, in many cases, the whole line must, in fact, be a level crossing where most people are pilferers, it becomes necessary to revert to such means as may place the railway in such a state, that it will watch itself in considerable length, without needing fences, or police, by having nothing practicable to pilfer.

In Egypt, up the valley of the Nile, there can be no need of these precautions. He would be a bold thief who would venture on appropriating any railway material belonging to Abbas Pasha. But there are other circumstances to contend against. The dry heat of the atmosphere is fatal to timber, and the soil along which the

Egyptian line will be carried, will vary from the extreme moisture of irrigated land to parched dust. Therefore, the deeper the foundations of a discontinuous sleeper road can be placed, the better chance there is of their remaining firm. What the effect of Mr. Barlow's saddle-back rail, or of girder-rails, would be, in such a climate, with an intense sun by day and with condensation by night, would require some careful experiment to determine. It is probable that ample provision for expansion and contraction would be required. In this case, a hollow girder-rail, with a free current of air through it, would be the best adapted for maintaining an equal temperature. Any of these kinds of rails, without timber, and with few parts, firmly fixed together, would offer little temptation to a marauder.

In hot climates, well peopled, when once introduced, railways will multiply as a means of health. They afford the most efficient means of obtaining the coolness, essential to keep down fever, and however stagnant the atmosphere may be, a locomotive at speed can always produce on a train of passengers the effect of a cooling breeze.

Such will eventually be the result of railways in the East. As the sea-breeze is called the 'Doctor' in the West Indian Islands, so will the railways of the East acquire similar names. The wealthy will make moving houses on the eastern railways, for the sake of an artificial climate wherein their jaded faculties may be restored.

In the flat parts of India, there are two evils to be guarded against; the flooding of the ground at seasons, which might float up a line, in which much buoyant timber was used, and the other is the white ant. It is doubtful, however, if the white ant would not find creosote disagree with his taste, quite as much as the teredo navalis finds it impede his tunnelling operations. It is apprehended, however, that all timber, in arid climates, would require to be well covered with ballast, to prevent injury from the hot cokes, from the ash-pan.

If broad flat stones could be used without ballast, and at a small cost, they would form a most valuable foundation; but stones cannot be used without timber, and fastenings, and therefore it seems probable, that continuous wrought rails of the compound girder form, may be best adapted for such circumstances; and if they be made wide enough to take an efficient bearing, on ordinary ground, as plank roads are made in America, they may be found the cheapest structure, and at the same time, a structure that manufacturers could turn out complete from their establishments, and which would require no skilled labour to apply.

It must be received as an axiom, that even where wood is

plentiful, it is not a cheap material. It requires much skilled labour to apply it—unless the form reduces it to machine work—and if the wood be hard it is very costly, and if soft, it has little durability, save by creosoting.

Girder-rails of sufficient size will probably be largely used in our Australian colonies, where, as in America, they cannot afford to pay policemen, and they require a structure, not easily damaged by carelessness, or wilfulness; a structure also, be it said, that affords peculiar facilities for moving from one district to another, if by change of circumstances a more eligible route were found, for be it remembered, that in such districts the bare 'way,' and the 'siding,' constitute almost the whole property of the railway.

The cost of the various kinds of structure examined, has not been here entered into, because it must vary with the locality, and the quality of the material; and the structure which is cheapest in one place may be dearest in another. It is also well understood, that cost depends chiefly on quantity, in a material practically without limit, such as iron.

An apology is perhaps due for the prolixity of this paper, recapitulating many things familiar to engineers; but when reflecting that the permanence of way must depend precisely on the details of its structure, and the care that is taken to guard against deteriorating causes, and which may sometimes make all the difference between a dividend and a loss, those who examine deeply will not consider the prolixity a waste of time.

In some of the views which he has taken, or rather in the elaboration of principles which must have occurred to all who have had time to think, the Author would disclaim all captious criticism. His object has been to arrive at mechanical truth, and to indicate in what direction further experiments should be made, in furtherance of railway progress, which is another result of the instinct that has prompted the great Anglo-Saxon race to push steadily forward, in this great work of civilization. For in truth the road is the great civilizer of humanity. People only quarrel with those they do not know. Give them access to each other and the quarrels cease. It is a marvellous instinct that prompts this law-loving nation and its offshoots to the work of road-making, and if he who makes two ears of wheat grow, where only one grew before, be worthy of an ovation, what shall be said to those, amongst the noble array of engineers, who will make two lines of railways at the cost of one?

The absence of roads is isolation, and if by some strange chance England should be deprived of her roads, and be prevented from reconstructing them, another generation might behold the inhabit-

ants reduced again to the condition in which they were found by Julius Cæsar.

From this state, roads have delivered us, under the dispensation of Providence, giving latent faculties to man. The most perfect road yet known is the railroad; and no higher service can be done to humanity than making railroads still more perfect, thus removing the chief obstruction to man's universal interchange of ideas, and the general spread of the benefits of civilization.

The paper is illustrated by a series of diagrams from which the woodcuts have been compiled.¹

Mr. W. B. ADAMS described the different sections of rails, of which diagrams were exhibited, and directed attention to a girder-rail of simple construction, hollow, so as to preserve as nearly as possible a uniform temperature, under the extreme thermometric variations between day and night, or even to serve as an occasional conduit, and also as a conduit for water, which latter, it was contended, might be advantageously employed in preventing the clouds of dust from which the passengers now suffered inconvenience, and at the same time causing more permanent contact between the ballast and the supports of the rails. This, he submitted, would be an efficacious, simple, and cheap mode of constructing the permanent way.

Mr. P. W. BARLOW objected, that the question of the cost of the permanent way had been almost entirely lost sight of, in the paper; now this was so important a consideration, in all constructions, that it should have been fully considered, before entering on the discussion of the various expensive innovations alluded to by the Author.

With respect to the system of cast-iron supports, for which he was responsible, it was necessary to state, that it had been proposed, before it was considered practicable to roll rails, either of such weight, or of such an extended section, as those introduced by his brother, Mr. W. H. Barlow, and now known as the 'saddle-back rail;' as soon as it was found, that such rails could be manufactured, he had advised their being tried, and he was fully satisfied with the result. Previous to that time, however, being under the necessity of determining the construction of about sixty miles of line, he had not hesitated to employ the cast-iron supports, which had, under the circumstances, fully answered his expectations. It must be admitted, however, that the saddle-back rail was, under ordinary circum-

¹ Several of the blocks, for the cuts, have been lent by members.—*Sec. Inst. C. E.*

[1851-52.]

stances, preferable; a single line of way could be laid with these rails, weighing 90 lbs. per yard (at the then low price of iron), at a cost of £900, or £1000, per mile. The portions of line so constructed, on the Midland Railway, were very successful; there was an even motion in the carriages, less noise at the joints, and evidently less wear and tear in the rolling stock, in spite of the rigidity of the rails. He apprehended, that the expense of the 'maintenance of way' would be considerably reduced.

Mr. W. B. ADAMS submitted, that the question of cost need not necessarily enter into the discussion, especially as the prices of materials were constantly varying, and the quantities being given, each engineer could make his own calculation as to first cost.

Mr. BRUNEL said, he was so fully impressed with the necessity for attempting to reduce the expense of maintenance of way, that he had not hesitated to try the 'saddle-back' rail, and as far as the limited experience of only twelve months enabled him to form an opinion, he was well satisfied with the result of the experiment, for although it had not yet induced the happy position, assumed by Mr. Adams, of there being 'no cost of maintenance of way,' there was every indication of considerable economy in the ordinary expense of repairs. The piece of railway, where the experiment was tried, was about seventy-five miles from London, and exposed to all the traffic of the Great Western Railway, under somewhat disadvantageous circumstances; yet it appeared to stand well, and, at present, the expense of maintenance of way was quite as low as that for the system of bridge-rail, with longitudinal timber-sleepers. It was well known, that Mr. Brunel was a decided advocate of the latter system of construction; he believed a line thus made to be at least as easily kept in order as with transverse sleepers; the joints were as readily made and were more solid, than those of any other system, and the cost of the original construction was not greater. The saddle-back rail appeared to possess most of these advantages, and at the same time to offer economy in the first cost; the joints, in particular, were rendered very even and secure, by fastening the ends of the rails upon a wrought-iron saddle-piece, with four, or six rivets, which united them perfectly.

He was so satisfied with the general result, that he had also used these rails on a short length of twelve miles, on a railway in Cornwall, and was about to adopt them for a considerable length on the South Wales Railway.

He must observe, that in the description, given by Mr. Adams, of the effect of traffic on bridge-rails and longitudinal bearings, results were mentioned which, during all his experience of the

system, had escaped his notice. The actual results of his first trial of the system were these;—the rails were too light, and being only attached to the timbers by a large sort of ordinary wood-screw, traversing the flanch of the rail and passing nearly through the timber below, the deflection, or 'creep' of the rail loosened the screws, and after being tightened down a few times, the holes became galled and the screws no longer held firm. They were then abandoned and were replaced by screw-bolts with the nuts on the under side of the sleepers; these in turn were reversed, the nuts being screwed on from above, and thus were accessible for constant examination; the corners of the heads were turned up, like fangs, to bite into the timber and prevent the bolt from turning.

When the bridge-rail was well bolted down, with small joint-plates, introduced beneath the junction of the ends, no system could give a smoother way for the carriages, or generally succeed better; it was, however, more expensive, in first construction, than Barlow's saddle-back rail.

It was generally considered necessary, in laying rails, to provide for their contraction and expansion. Now, however strange the assertion might appear, Mr. Brunel did not hesitate to state, that such provision was unnecessary, under ordinary circumstances, in this climate. This would become evident, when it was considered that 10° or 12° of heat only represented an amount of expansion equal to 1 ton per square inch of pressure; now if the rails were held very firmly by their fastenings, there would be sufficient resistance to counteract any effect of contraction, or expansion, between the points of attachment, as a change of temperature of even 50° would only render it necessary to provide for a tension, or compression equal to 5 tons per square inch in the whole, or $2\frac{1}{2}$ tons alternately, of extension and compression.

A fact had been mentioned to him, by Mr. Hawkshaw, relative to a cast-iron parapet, which completely confirmed this view, and it was found, that in riveting together the ends of the bridge rails, the same effect was produced. When this was first mentioned, everybody doubted it, and to satisfy himself, Mr. Brunel caused a length of 100 feet of rails to be welded together, and another length of a quarter of a mile to be riveted together, with accurate gauges fixed at each end; the result was conclusive, that there was not any accumulated motion, either at the extremities, or in any part of the two lengths. This and other subsequent trials convinced him, that it was only necessary to fix the rails securely upon steady sleepers, to provide against every tendency to contract, or expand, arising from the variation of temperature in this climate, although in a very hot

summer he had found the surface of the rail heated to as much as 130° .

With respect to the various modifications of the forms of rails, proposed by the Author of the paper, in the diagrams exhibited, and with every desire to remark courteously on the papers kindly prepared for the meetings, he must say, that he could not find any suggestions calculated to advance the practice of laying permanent way. They might be ingenious, but they were not useful, and most of the forms had been already tried and condemned.

As to the split-rail, stated to have been tried in America, there was no experience of its use in this country, to enable an opinion to be hazarded upon its utility. The arguments in favour of the girder double rail were based upon assumed, but not demonstrated, defects in the saddle-back rail, and it did not appear that any experiments had been made, to prove either the positive existence of the defects, or of the merits of the proposed plan for obviating them. It was presumed, that the saddle-back rail did not take a solid bearing on the ballast, in consequence of the difficulty of packing it; now it was well ascertained, that ballast of almost any kind became, in time, so perfectly rammed into the cavity, that a nearly solid mass was formed, whereon the spreading flanches took a solid bearing, at a sufficient depth to receive the necessary lateral support, without that hindrance to perfect drainage which would be likely to occur from an extreme depth of web, unless there was such a thickness of ballast as would be very expensive in practice. On the other hand, the shallower proposed forms had the disadvantage of taking their bearing so near the surface, that the packing would be affected by any slight changes of weather.

With good materials, and judgment and care in applying them, a practically perfect permanent way could be made, either with stone blocks, or transverse sleepers and chairs, or with longitudinal timber-bearings and bridge-rails, and any of these systems were preferable to the proposed modifications; but Mr. Brunel hoped, that with Barlow's saddle-back rail a permanent way as good, or nearly as good as any of these, might be constructed, and at a less cost.

Mr. ASHCROFT said, from his experience of the system of 'fishing' the ends of the rails, on the Eastern Counties Railway, where it was already tried upon a length of twenty miles, he was of opinion, that there would be an economy of fifty per cent. in the cost of maintenance of way; and he thought, that by the application of the 'fishes,' to retain the ends in the same plane, and to render

them steady under the wheels, any line, with transverse sleepers and chairs, could be cheaply put into, and be easily retained in, good working order.

Mr. BIRD said, he had been informed, by eminent German engineers, that 'seite laschen,' which were nearly identical with the 'fishing-plates,' had been used for several years in Germany. On the railway between Leipzig and Dresden, which was nearly the first line executed in that country, having been constructed in the year 1838, a portion was laid with single T rails and 'seite laschen,' holes being punched in the ends of the rails for these fastenings. They had subsequently been employed, throughout the entire length of the Lubeck Railway, and were tried on many other lines; indeed the 'seite laschen' were included in most of the specifications; their form was such as to allow them exactly to fill the cavity on each side the rail, immediately beneath the top table, and they were held together by transverse bolts and nuts. On the railway near Olmutz, in addition to the 'seite laschen,' the two lines of rails were connected transversely by long bolts, to preserve the gauge accurately. In Rhenish Prussia the ends of the rails were connected by 'seite laschen,' of such a form as to adapt the upper part to the vertical web of the rail, and with a horizontal web to be attached to the sleeper. He was not aware, that in any part of Germany fishing-plates, between the supports, had been adopted.

Mr. SAMUEL was not aware of the 'fishing-plates' having been adopted in Germany, otherwise than as a means of keeping together the ends of the rails in the joint-chair, of which they merely extended the hold on each side. He had never seen them used, in Germany, with the suspended joint, in the manner he had employed them on the Eastern Counties and other lines.

He gathered from the paper, that Mr. Adams claimed the invention of the fished suspended joint; the claim was perfectly valid, and Mr. Samuel had become first connected with it, by introducing it practically on the Eastern Counties Railway. He subsequently used a 'fished-joint chair,' which he considered a valuable modification of Messrs. Adams' and Richardson's 'fish-joint;' it was capable of easy application to the permanent way of a line of the ordinary transverse sleeper construction, and had the merit of avoiding interference with the usual position of the sleepers and rails, which became inevitable, when the ordinary 'fishing-plates' were applied to a permanent way already laid down. The result of the experience of several miles, laid on this system, on the Eastern Counties Line, had been very satisfactory.

Mr. BRUNEL had always understood, that it was to Mr. Samuel the railway world was indebted, for the valuable introduction of the 'fishing-plates' with the suspended joint, and all who had noticed the even surface of the rails and the smoothness of the travelling, on the portions of the lines so treated, must admit the great advantages of the system.

Mr. P. W. BARLOW would correct an impression which appeared to obtain, as to the extent of fracture of the cast-iron bearing-plates on his system; now the fact was, that the amount of breakage did not exceed that of the cast-iron chairs, on railways of the ordinary construction. He was convinced, that under all circumstances, the cast-iron bearing-plates could be economically employed, and this opinion was confirmed by the offer of Mr. Taylor, the contractor, to maintain and renew, for twenty years, that portion of the South Eastern line, laid with cast-iron bearing-plates, for £100 per mile per annum. It must be borne in mind, that the portion of line alluded to, was that on the Greenwich and the main line, where, from the confluence of so many trains, the traffic was nearly three times as great as the average of that of the other portions of the railway; and also, that the rails had been more than ordinarily degraded, from the employment of bad ballast.

In a Report he had recently made, on 'Permanent Way,'¹ he had given the details and the results of some extended experiments, having for object, 'to ascertain whether the weights of iron required to obtain the necessary bearing surface, and, at the same time, to insure against fracture, would make the cost greater than the value of the increased durability of the material;' and without troubling the meeting by a recapitulation of the particulars of the Report, to which he would beg to refer them, he would confidently state, that the cost was even less than that of an ordinary wooden road.

The experience he had, in the maintenance of way, convinced him, that after the selection of a good quality of ballast, the cost of maintenance of a line depended on the extent of bearing surface, which should be so obtained as not to interfere with the drainage. It would appear, that in the commencement of the railway system, the engineers had admitted this fact, as with five stone blocks, each 2 feet square, at intervals of 3 feet from centre to centre, under each rail of 15 feet in length, there was an extent of bearing surface of 40 feet, under each pair of rails on a single line. On some of the more recent railways, with transverse timber-sleepers, the extent of

¹ Vide Report on Permanent Way, by Peter W. Barlow, addressed to the Directors of the South Eastern Railway. 4to. London, 1849.

bearing surface did not exceed 24 feet, part of which was useless, as the plate-layers only packed about 18 inches on each side of the chair. In the estimate of cost of his system of cast-iron bearing-plates, he assumed 28 feet of surface, and he believed that would be found sufficient for heavy traffic, as from the proximity of the base to the surface of the ballast, complete drainage could be obtained.

He understood it to have been stated, that the actual cost of maintaining the transverse timber-sleeper permanent way of the South Eastern Railway, had not exceeded £30 per mile for six months. He must be permitted to observe, that it was very possible to reduce present expenditure, at the risk of deterioration of the road, and that half a year was a very limited period to judge from.

He had tried two small pieces of line laid with Greaves' iron-sleepers; on one piece, no breakage occurred, but on a part of the railway, where the heavy engines passed over at full speed, several of the castings had been broken; he thought they had been made too light to bear the severe test of heavy engines, with hard gravel ballast upon brick arches. They were generally reported to stand well, requiring less repair than the ordinary sleepers. The cost of Greaves' system, if equal strength of metal was used in the sleepers, was necessarily greater than Mr. Barlow's cast-iron bearing-plates, with equal bearing surface.

The quality of timber employed for the sleepers, and the mode of preserving them from decay, were important questions, in the maintenance of permanent way. He believed the most economical system was, to use only the soundest timber that could be obtained; and after trying the processes of Kyan, Payne, and Burnett, he must admit that the only one which had not completely failed was Bethell's process, which was saturation with creosote.

Mr. W. H. BARLOW explained, that the introduction of the saddle-back rails, on the Midland Railway, arose from the great expense incurred in renewing the timber-sleepers. In the first instance, he proposed a rail weighing 127 lbs. per yard, but in spite of the exertions of the manufacturers, for which they were entitled to great credit, the difficulty of manipulating such masses of iron was so great, that, as a temporary expedient, a length of about nine miles was laid with cast-iron bearing-plates, beneath rails weighing 80 lbs. per yard; the weight of the bearing-plates was about 300 tons per mile, and although the road was laid under circumstances of considerable difficulty, it had completely succeeded, and he would not desire to have a more perfect length of line; the

maintenance of a portion of this length had recently been let to a contractor, for £42 per mile per annum; this demonstrated the economy of the system. The rails were 20 feet long, with two rigid cross-ties, formed of bars so deep and stiff as to maintain the bevil of the rails, which was a very important feature in all permanent way.

As soon as the manufacturers had completed their arrangements, a length of way was laid with saddle-back rails, weighing 127 lbs. per yard, resting on cast-iron joint-plates, into which the rails were keyed; this formed a very durable road, requiring very little maintenance. Subsequently, finding there was an excess of strength, the weight of the rail had been reduced to 100 lbs., and was now being still further reduced to 90 lbs. per yard, the joints being made by riveting the meeting ends upon an internal wrought-iron saddle-piece, somewhat similar to that used by Mr. Brunel and Mr. Hawkshaw, for bridge-rails on longitudinal timbers.

The traffic of the Midland Railway was, from local circumstances, peculiarly heavy, and like all narrow-gauge roads, laboured under the disadvantage of the want of base so requisite for heavy traffic and high speeds; the cross-ties had therefore been extended on each side beyond the rails, and with considerable advantage.

The cost of a line, with saddle-back rails weighing 90 lbs. per yard, when those rails were costing £6 per ton, was £2,100 per mile for the two lines of way.

Mr. W. B. ADAMS had assumed, in his paper, that the permanent way was a constant source of expense, arising chiefly from the deflection of the rails, and the sinking of the sleepers, under the pressure of the passing loads. These effects, he argued, could only be obviated, by giving to the permanent way a certain amount of rigidity, upon an elastic absorbent, which would be best obtained by using deep stiff rails like girders, with lateral strength, and plenty of bearing surface on the ballast, so as to avoid the undue depression of the substratum. For these reasons, although, he believed, not strictly in accordance with the regulations of the Institution, he had ventured to suggest some hitherto untried forms of rails and methods of supporting them, which he felt convinced would attain the end which was admitted to be very desirable.

Captain W. S. MOORSOM, in reference to Mr. Brunel's observation, was of opinion, that only under peculiar circumstances, could the usual precautions, against the effects of expansion and contraction, be dispensed with. The experience of Mr. Brunel and of Mr. Hawkshaw was certainly conclusive (as far as it went), but on the other hand, there were many instances of lengths of line being forced

out of gauge, or lifted up, on sudden changes of temperature, owing, it was supposed, to the rails being too firmly fixed in the chairs. He had seen a length of nearly half a mile so lifted, on a railway under his charge; he therefore again recommended caution in disregarding the effects of changes of temperature.

The general questions of the first cost, and of the subsequent expense of maintenance of the permanent way, were of vital importance in railway economy, but he thought more details should be given, to enable a correct appreciation of the value of the various systems to be arrived at. The cost per mile of Mr. Barlow's saddle-back rail appeared low, but probably the amount stated only included the rails and the labour of laying them, without the ballast. This should be distinctly explained.

The data essential for making a comparison between the first cost, and the subsequent maintenance of different systems of permanent way, should comprehend—

1. The weights, and quantities of the respective materials.
2. The prices of the same—in place, and the amount per mile.
3. The character of the ballast.
4. The description of engines used on the road.
5. The number of trains—per annum.
6. The speeds.
7. The length of way subject to this traffic.
8. The time during which the expense of maintenance had been experienced.
9. The cost of maintenance per mile, per annum, including all materials and ballast.
10. The cost of maintenance, per train, per mile run, per annum.

As an example of his meaning, he would give a sketch of the particulars of the construction of the Waterford and Kilkenny Railway in 1846, when iron was at the high price of £12 per ton.

The sleepers were continuous longitudinal bearings of half balks, cut to an isosceles triangular section, with stiff cross-ties forming struts also. The double I rails weighed 56 lbs. per yard. The chairs, cast by Messrs. Ransomes and May, of their ordinary pattern, but with a parabolic section on the length of the bed, weighed respectively, for the joints, 27 lbs. each, and for the middle bearings, 14 lbs. each; the saddle-pieces weighed 7 lbs. each. The lengths of bearing varied from 30 inches, in the middle, to 15 inches at each end of the rails, before reaching the joints.

The first cost of this permanent way, if the rails cost £7 per ton,

the chairs and saddles £5 per ton, and the timber for the sleepers 1s. 6d. per cubic foot, would be per mile of single line of way—

Rails	£ 616
Chairs and saddles	143
Pins, trenails and keys (Ransomes' and May's compressed)	87
Timber-sleepers, ties and dowels	453
Cost of laying	88
Total cost per mile	£1,387

The railway, about thirteen miles in length, with a gauge of 5 feet 3 inches, had now been regularly travelled over, for between three and four years, by eight, or ten trains daily on each line, making about three thousand trains per annum. The weight of the locomotives used was about 22 tons, and the average speed of the trains was twenty-four miles per hour.

The cost of maintenance of way, including the renewal of all materials and ballast supplied, since the line had been out of the contractor's hands, had been, for the first year, £53 12s. per mile; for the second and third years, £35 12s. per mile; and for the first half of the current year, at the rate of £31 per mile per annum, or at the rate of 2·51 pence per mile run, per annum.

He believed this cost of maintenance was less than that of many lines of equal traffic.

Mr. R. J. Hood thought it was almost impossible to draw an accurate deduction, as to the comparative cost of maintenance of way, from any published reports, as it was rarely stated what was included under that head; for instance, on one line it was strictly limited to keeping up and renewing the lines of way, the ballasting and the ditches; whilst on another line the keeping up the fences would be included, and perhaps on account of the vicinity of the line to populous districts, the fencing was of an expensive kind. He agreed with Captain Moorsom, in the necessity for specifying everything very clearly.

As to the modifications of forms, proposed in the paper, they appeared to be chiefly untried attempts, to remedy some of the acknowledged evils of existing systems, but he could not agree in commending them.

Cast-iron sleepers had been laid down to some extent on the Brighton Railway, but Mr. Hood dreaded the expense of repair and of their renewal, or, what was more probable, the substitution of some other system. There were also, on the same railway, some

bridge-rails laid on transverse sleepers; it was not a satisfactory system, and was frequently out of repair.

The 'fished' suspended joints were decidedly the best, even with only four, instead of five sleepers; he used 'fishing-plates' 18 inches long, with four transverse bolts $\frac{1}{2}$ inch diameter, and found the surface of the rails so even, that the rolling stock was less injured than before their adoption. He was certain that system would diminish the cost of maintenance of way.

Mr. HAWKSHAW corroborated the statement, as to the apparent absence of expansion and contraction, in lengths of iron securely tied down. About ten years since he erected at the station of the railway, at Salford, a parapet 750 feet long, composed of cast-iron plates, each 9 feet long, and 1 inch thick, firmly riveted together, and held down tightly; it retained a perfectly straight line, under all variations of temperature, without any special provision being made for contraction, or expansion.¹

He commenced using the systems of fishing rails, and of riveting them firmly together in long lengths, as far back as in 1846: one end of the joint-plate being riveted to the rail in the works, and the other on the line, when in place; no ill effects had ever been experienced, on his lines, from changes of temperature.

When rails were driven hard up endwise against each other in the joint-chairs, without there being fishing-plates to keep them down, and in the same plane, there was when under expansion a tendency in the rails to rise. The best feature of the fishing-plates was their power of holding the ends of the rails firmly down, and of keeping the travelling surface even.

The question of the relative cost of maintenance of way could not be properly discussed, without a minute detail of all the dates and circumstances. For instance, a line under his charge was constructed for some miles across a coal district, where, in consequence of the under-ground workings, the surface constantly subsided, and, of course, a large quantity of ballast was required to restore the level, independent of the constant labour in packing and keeping up the line for the traffic. The mechanical questions of good forms and proportions, of good quality of materials and of ballast, and of care in construction, were now generally well understood, and the best systems were acknowledged to be the cheapest in the end. He must repeat, that the cost of the maintenance of way was so dependent on a variety of circumstances, that it was extremely difficult to form a comparison between any two lines.

After very extensive experience of almost all ordinary forms of

¹ Vide *ante*, page 241.

rails and systems of construction, he gave the preference to a strong bridge-rail, firmly attached to longitudinal bearers of sound balk; this he, at present, considered as the best system of construction. He did not think that the fibre of the longitudinal timber-balk was more crushed under the bridge-rail, than that of the transverse sleepers under the chairs; and he believed the cost of maintenance of way to be somewhat less with longitudinal, than with transverse sleepers.¹

He had used Greaves' cast-iron sleepers successfully, and he was of opinion, that in certain situations, particularly where the sand was used for packing or the gravel ballast was small, the system would answer well; on some foreign railways they would be found useful; particularly in the East, where only such timber could be used as was known to resist the ravages of the white ant, and there it was sometimes expensive and difficult to be obtained.

Mr. C. MAY directed attention to the joint-chairs, slightly alluded to in the paper; cast in 1849, by Messrs. Ransomes and May, at Ipswich, from the design of Mr. John Fowler, M. Inst. C.E. The object of the extended chair was, to prevent the injurious effect on the rolling stock, and permanent way, arising from the ends of the rails being permitted to move, as in the joint-chairs of the ordinary construction. This evil had been felt by all engineers, and there were few who had not attempted a remedy. Mr. Fowler had tried an experiment on one mile of line, under very considerable traffic, and, after an experience of two years, he expressed himself satisfied, that there was less action at the ends of the rails, which were held down more firmly, the injurious effects on the rolling stock were diminished, and the cost of maintenance of way had been reduced.

This joint-chair (Fig. 20, page 261) was 2 feet 6 inches long, and had three jaws on each side, so as to hold the ends firmly for 15 inches of each rail, giving that length of solid bearing.

Experience had shown, that the body of the chair might be shortened about 9 inches, without diminishing its utility, as its length was determined by the power of properly packing the two sleepers on which it rested. Only three chairs had been broken, in two years, and those all near the same place, showing that a slight addition of metal to that part would be beneficial.

It was not contended, by Mr. Fowler, that this was the best method of securing the end of the rails; but as it had proved suc-

¹ In Mr. Hawkshaw's Report on the Rolling Stock and Permanent Way of the Lancashire and Yorkshire Railway, for Manchester, 1850, these points are discussed with great minuteness.—*Sec. Inst. C. E.*

cessful, and it was not the object of a patent, he had requested Mr. May to lay the facts before the meeting.

Mr. WILSON corroborated the statement relative to Mr. Fowler's joint-chairs; they had been used, in 1849, on the Lincoln branch of the Manchester, Sheffield, and Lincolnshire Railway, where there was considerable traffic, with heavy engines, and at high speeds; they were subjected to severe trials, by running engines, at considerable speeds, over obstructions $\frac{1}{2}$ inch in height placed on the rails, over the joint-chair, and the shocks were borne without any injury to the joint. The bearing was originally 2 feet 6 inches long, but it was found, that the base of the chair might safely be reduced to 1 foot 9 inches, which had been done, without diminishing the steadiness of the chairs. The part of the line, on which they were used, was excellent, and the cost of maintenance of way was less than in other parts.

Mr. ALLPORT confirmed the evidence, as to the length, on which these joint-chairs were used, being the best part of the whole line, although it was subject to the action of the heavy engines and trains of the Great Northern Railway, passing over it at considerable speed.

Captain SIMMONS, R. E., being fully impressed with the importance of the subject, had listened with much attention to the discussion of a question which, however, he thought was of too great magnitude to be fully canvassed at a meeting of the Institution; he would, therefore, confine his observations to a very few points.

He had made some experiments on the permanent way described by Captain Moorsom, as at first he entertained some misgivings as to the solidity of the line, on account of the apparent weakness of the rails, the distance between the main chairs, and the absence of power in the intermediate saddle-pieces to afford lateral support to the rail; the experiment might, however, be considered generally satisfactory.

In considering the original construction of the railway, and the cost of maintenance of way, he thought that the amount of resistance to trains should be imported into the calculation. It had been stated in evidence, that at a speed of 60 miles per hour there was a resistance equal to about 60 lbs. per ton, on a narrow-gauge line, whilst, at the same speed, the resistance was reduced to 18 lbs. per ton, on a broad-gauge line. Now as there was not any very great difference in the form, arrangement, or weight of the locomotive engines on the two lines, he had been at a loss to account for the stated difference of resistance.

He would now venture to suggest, whether the difference might not, to some extent, proceed from the different systems of forming the line; the longitudinal bearing affording that regular and continuous vertical and lateral support to the rail, which it only received at intervals from the cast-iron chairs on transverse sleepers; whilst, with the latter system, it was very difficult to prevent a certain amount of rocking motion in the chairs, which must produce considerable resistance; and at the joints, unless the rails were very heavy, or were 'fished,' the resistance was very much increased.

The system introduced by Mr. Fowler appeared to be a decided improvement; the joint-chairs were very steady, and the increased length, of 30 feet, given to the rails, was a very advantageous innovation, as it got rid of half the usual number of joints; provided, however, that the extra cost of such heavy lengths of rail did not militate against the introduction of the system.

Captain Simmons had examined the roads laid with Mr. W. H. Barlow's saddle-back rails; the line appeared to be good, and the construction solid; the principal objection against it seemed to be the anticipated heavy expense of renewal, when the upper table of the rails should be worn down, or the surface be laminated, or cracked. In conversation on the subject, with Mr. Morris Stirling, he had been informed, that it was practicable, at a slight expense, to impart a very durable surface to the rails, by the introduction of a mixture of metal during the process of rolling; that the compound metal, welded perfectly, and was as tenacious and much harder than the ordinary rails. If this process could be adopted, at a reasonable cost, it would prove a most advantageous adjunct in the use of Mr. Barlow's saddle-back rail.

The cast-iron bearer-plates, introduced by Mr. P. W. Barlow, had also received his attention; they appeared to have answered well, where they had been originally well packed and had been carefully attended to; but they were liable to fracture, if the substratum was not constantly kept well rammed beneath them: in short, like almost all other systems, if it was well attended to, it was durable, but, if not, the cast-iron way as soon got out of order as any other road.

Mr. BRUNEL was anxious not to be misunderstood in what he had stated, relative to the contraction and expansion of rails; he did not mean to imply, that iron rails were exempt from the ordinary effects due to changes of temperature; but that when rails were effectively held down to longitudinal, or other firm bearings, the effect of the amount of contraction, or expansion, occurring under the limited

range of alterations of climate in Great Britain, would be resisted, and thus would not produce any of the effects of buckling upwards, or curving outwards, which would occur on lengths of rail inefficiently attached to the sleepers. He had tried lengths of several miles of rails firmly riveted together, and securely attached to longitudinal sleepers, without finding any ill effects from the contraction, or expansion.

He desired also to be understood, as to the opinion he expressed upon the numerous modifications of forms of rails exhibited in the diagrams, many, if not all of which, were made the subject of patents, although they had not been tried in any way, and most probably no person would ever attempt to try them; the only effect, therefore, to be anticipated from this accumulating of numerous fanciful forms in one patent was, that when a really good form was devised, it would be found to bear so close a resemblance to some one of these imagined sections, that either the use of the positive improvement would be prohibited, or a fertile field would be opened for litigation, on a case of infringement. For instance, some of the new forms shown, though in themselves impracticable, or objectionable, would have sufficed to prevent the use of Barlow's saddle-back rail, which though, perhaps, not positively new in form, must be admitted to be a decided improvement upon the rails of that description in ordinary use, and to be a good disposition of material; there was a good bearing, sufficient depth to give stiffness, and a breadth of base to insure firmness. Now the employment of this saddle-back rail, which was rather remarkable for its judicious proportions, and the good disposition of the metal, than for its novelty, might (as he before said) have been precluded by some such fanciful sections as those which had been theoretically advocated, although, he must say of them, that among them there was little that was new, and that little was not good. It was notorious, that engineers frequently found their practice restricted, by the claims of some theoretical patentee, whose obsolete invention never would have been heard of, but for the adaptation, in practice, of some, perhaps the only useful, portion of an invention, originally applied to some widely-different purpose. He feared that he should incur the ire of the inventive world but in these discussions he held it to be incumbent upon the Members; to give their unfettered opinions, however heretical they might be considered.

Reference had been made to the principle of having a false top to rails, to be removed when it became abraded, or laminated by the traffic. Now though this sounded well theoretically, it was generally considered to be useless in practice. Throwing aside the

danger and other disadvantages, liable to result from the use of a rail composed of so many parts, as would be necessary for the removal and replacing of a false top, it would suffice to consider the monetary part of the question. If a rail weighing 90 lbs. per yard required to be changed, it was true that another rail of the same weight must be substituted, but the old metal could be re-rolled and converted into new rails at an expense of about two pounds per ton, which would probably be less than the cost of replacing the false tops in more complicated rails. It had been admitted, that the average duration of rails was ten years, and many engineers contended for a much longer duration; now a very simple calculation would suffice to demonstrate, that after ten years' use, it would be cheaper, and certainly much more economical in practice, to take up the entire rail, than to take to pieces and refix a complicated subrail, in order to replace the upper table. As a matter of figures, it must be evident, that at the present price of iron and with the actual facilities for rolling rails, no positive advantage could result from renewing the upper table of any form of compound rail yet proposed.

Mr. Brunel trusted that the remarks he had made would not be considered invidious: but he felt strongly the prejudicial effect of the present system of accumulating in one patent almost every possible modification of form, or process, and thus obstructing, if not frustrating, the attempts of others to introduce improvements which would become the unrestricted property of the public.

Mr. W. B. ADAMS, in answer to previous speakers, considered, that the amount of expansion and contraction must depend very much on locality and circumstances, as the iron might be laid where the heat would be carried off with such rapidity as not to affect the metal. It might, no doubt, be practicable to overpower a given force of expansion and contraction, by a greater force holding down the rails, but it then became a question whether it was desirable to do so, and whether the iron might not be injured, by the unnatural restriction to which it was subjected.

He could not comprehend, how the ballast remained firmly pressed upwards into the apex of the interior of the saddle-back rail, when the vibration occasioned by the travelling was considered, and he thought the deep cross-ties, necessary for preserving the inward level of the upper table, indicated a certain tendency to unsteadiness in that form, although its base was so widely spread.

With respect to the use of the fishing-pieces, he thought common sense must point out the advantage of giving to the joints, which were the weakest parts, such an amount of support, or stiffness, as would render them as steady as the intermediate parts, and in no

manner could this be done so simply, or so effectually as by applying what might be termed 'splints,' to unite the two ends and impart to them as much strength as was possessed by the body of each rail, even if as much weight of metal was abstracted from the entire length as would supply the fishing-pieces; by this means the cost of fishing was much reduced. Experience had shown, that by the application of the system to old lines, the expense of relaying was avoided, and the increased comfort to the travellers, and the diminished wear and tear of the rolling stock were generally admitted.

The experiment tried by Mr. Hartley, had proved, that a certain elasticity of substratum was essential for a good permanent way.

He must submit, that the opinions, adverse to the forms of rails proposed in the paper, had been supported by assertion rather than by argument, or by the deductions of experience. If the various forms and arrangements were as defective as had been stated, they could not, by the simple fact of being included in a patent, become sufficiently important to interfere with the inventions, or improvements of engineers. The cast-iron subway, the saddle-back rail, the chilled chairs and wooden trenails, innumerable turn-tables and switches, and almost all the various parts composing a railway were already patented, so that, at all events, if there was any error in accumulating several forms in one specification, the sin had been committed, in emulation of very numerous, if not very good, precedents. The discussion of the question, whether patents should be permitted to be secured at all, belonged rather to another subject, and should not be imported into the present proceedings.

The moveable top for the rail, which had been so strongly objected to, had been proposed merely for certain localities, where the difficulties and cost of transport of rails of heavy weight would be considerable, when it should become necessary to replace the original rail. There were other forms, more analogous to the saddle-back rail, with which the latter might have been more correctly compared. There was a marked mechanical distinction between the saddle-back rail and the solid girder rail. In the specification of the former, it was described as "a trough rail bearing on the ballast and riveted to bearers," and the intention was, by widening a bridge rail to obtain a broader base. In the latter, the object was to obtain a T girder of such a depth as would prevent undue deflection, and with sufficient breadth to give ample bearing surface on the ballast, whilst the tread of the rail should be so slightly elevated, that there should be little, or no tendency to lateral yielding, or rocking.

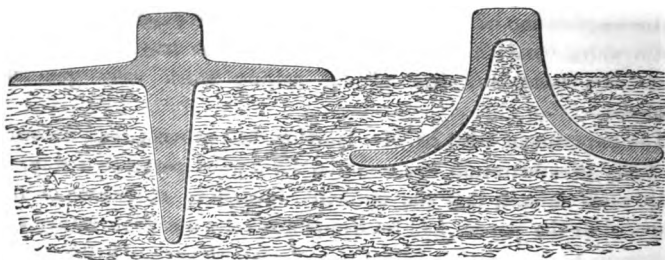
In fact the saddle-back rail might be said to represent the shallow
[1851-52.]

U

bridge rail of the longitudinal system, whilst the deep girder rail exemplified the T section of the transverse sleeper system.

A comparison of the actual proportions of the two forms would show (Fig. 25), that the girder rail possessed more bearing surface

Fig. 25.



Adams' Girder Rail.

Barlow's Saddle-back Rail.

on the ballast, combined with a deep keel to prevent oscillation, and there was no greater difficulty in packing one form than the other, or rather, if there was any difference, it was in favour of the girder rail. As to the cost of manufacturing the deep girder rail, the same objections had been raised to the saddle-back form, but they had been overcome by the energy and skill of the iron manufacturers, and if there was a positive advantage in any given form of rails, means of producing them at moderate cost would soon be discovered. A crack, or flaw in the horizontal top of a "saddle-back" rail, would seriously injure it, but such a crack in a "girder-rail" would not impair its efficiency. The matter resolved itself into the question of which form, with a given weight of iron, offered the best bearing surface on the ballast, and possessed the greatest number of collateral advantages. Experience alone must decide; meanwhile Mr. Adams felt bound to endeavour to clear himself from the imputation of having proposed forms without ideas. The object of the paper was to direct attention to the T girder rail and its varieties;—to suggest the resumption of stone blocks, combined with either transverse, or longitudinal timber-sleepers;—the substitution of durable materials for the perishable ballast now in use;—giving to the rails a sufficient amount of elasticity to avoid the jarring which now acted so prejudicially on the rolling stock, and detracted from the comfort of the passengers;—and whilst providing for the drainage of the ballast, to afford the means of employing water, in dry seasons, for consolidating the packing, and laying the dust during the passage of the trains. In treating these various topics, the mention of the proposed methods

for meeting certain difficulties, or for obtaining certain ends, was unavoidable, and experience had shown, that in bringing forward any new proposition, unless the first claim included every apparent mode of attaining the object, an unscrupulous improver, seizing upon the idea which had cost the inventor much thought, would, by a slight modification, obtain the credit and reap all the advantage of the invention.

When in 1847 Mr. Adams specified the "fish-joint," for the double-table rail supported on chairs, he thought that a good and valid title to an original idea had been recorded; but a host of followers in the same track immediately obtained patents for improvements, on the method of securing the joint of the double-table rail, used with chairs. This experience determined him, in future, to combine as many of these, so called, improved forms, or optional modes, as his imagination could supply, in order to avoid those disputes, which the protection of a successful invention was nearly certain to induce.

It was well known, that upon all lines of railway, there were used a multitude of patented inventions, and therefore, inventors might be permitted to hope, that even Mr. Brunel's antipathy to patented inventions would eventually be modified, and that the deep girder rail might be admitted for trial on the Great Western, or some other line of railway.

Mr. ERRINGTON said more reference should have been made to the use of stone blocks for railways, as, although they had been generally discarded in Great Britain, he thought there were many localities where stone might be used with advantage. It would be well to inquire into the causes of the block road being so completely abandoned. He had recently examined the Lancashire and Preston Railway, which had been open for twelve years, and in that period the blocks had only been replaced, to the extent of one-fiftieth of the whole.

The timber sleepers on the line had been replaced to the extent of one-half, though they were of excellent quality, and had been supplied at a time when there was no difficulty in getting larch timber. One-fortieth of the quantity of rails had been replaced, and it would now be requisite to replace one-twentieth more. The chief injury to the rails appeared to have arisen from the splitting at the joints, which clearly pointed out, that "fishing," or some other system, than had been hitherto pursued, was required. Whether, ultimately, there would not be a great deal of wear and tear, even with that new system, appeared doubtful, as the nuts, bolts and fishing-pieces would probably have to be replaced.

With reference to the cost of maintenance of way, it was desirable to define what was meant by the term. In a document, published under the authority of the London and North Western Railway Company, it was stated, that the cost of the road, over an average of four hundred miles, had been hitherto £200 per mile per annum. Now it was impossible, that the small sums (£70 to £100) mentioned for maintenance of way, could comprise the same items as those in the document alluded to; he had known cases where, on one mile of railroad, there had been deposited 2,000 cubic yards of ballast, in one year. The upholding, referred to in the London and North-Western Railway Report, included the maintenance of every great work on the line—bridges, tunnels, slips, drains, and ballast, in fact, everything an engineer could desire to have done, in order to preserve a perfect plane for the rolling stock, and that condition was generally rigidly enforced. In some cases it was not usual, in maintaining a road, to replace a key, or spike, or rail, the moment it was wanted, and to include it in the maintenance, but it was reserved for a future time, when the cost was included in that of more special restoration out of the capital. He thought, on the present occasion, although the object was, perhaps, rather to discuss the mechanical merit of certain forms of construction, yet in so purely commercial a matter as a railway, the vital question of cost should not be lost sight of. It was yet to be proved, whether the saddle-back rail could be maintained at anything like the expense that had been stated; but he could not believe, that in the price named, anything approaching to a general maintenance of way had been included. It was therefore desirable to obtain further information on that point.

Mr. P. W. BARLOW stated, that the cost of maintenance given by his brother at £42 per mile, included the upholding of the fences, ballasting, and the ordinary repairs of the road; any extraordinary expenses, such as the giving way of tunnels, or other large works, or large slips, were not included. Everything was comprehended that would be comprised in a contract for maintenance. Mr. Wythes, the Contractor for maintaining the way with cast-iron bearings, had informed him, that when the road was consolidated, one man per mile would be sufficient to keep it in repair, and in that he included the ordinary cost of fences and of maintaining the road.

Mr. BIDDER said much valuable time had been wasted in the discussion of the speculative portions of the paper, which he thought was not quite of the character pointed out in the list of subjects circulated among the members of the Institution. No more important subject could be treated of, than the construction and

maintenance of permanent way ; a paper on such a subject ought to enter fully into detail, and the first thing to be clearly ascertained was, what was meant by the term "maintenance of way," which was stated to have cost all sorts of sums, varying between £42 and £200 per mile. Descriptions of the mode of laying transverse, or longitudinal sleepers were not required, but a paper on this important subject, should have traced the results of all the experiments upon, and trials of, the various systems which had been tried. Now the paper under consideration chiefly contained observations on a great many forms of rails, but did not attempt to supply information on the methods of doing the best work in the most economical manner, whether in the construction of a new line, or in repairing an old one.

Allusion had been made to the rail first laid on the Blackwall Railway ; it had bevelled joints, which were described as being weak ; now in fact the joint was not weakened, as it was made by twisting the web of the rail and cutting off a portion of the protuberant end. The rail was certainly rendered somewhat more expensive, by the introduction of a process, which he would recommend on every railway, namely, by causing the iron to undergo additional hammering in the course of the manufacture ; that had only cost thirty shillings per ton, and he believed the extremely durability of the old rails was, to some extent, owing to the extra-manufacturing process to which the iron was submitted. If instead of introducing large and heavy rails, a more perfect mode of manufacture had been sought for, he thought they would have had more economical railways.

The great question (although he admitted they were scarcely in a condition to settle it) was, which was the best system of construction to be adopted, at the present time, for a new line of railway ; they would have to choose between the longitudinal system (which was, perhaps, brought to the greatest perfection by Mr. Brunel),—the transverse system,—and the saddle-back rail. There remained then to be considered, the prices of wood and of iron, the relative durability of all the materials employed, and their value when renewed. If the price of wrought-iron was assumed to be £5 10s., and cast-iron £4 per ton, and sleepers 4s. each, it was practicable to use heavy rails, and cast-iron bearings, if otherwise deemed advantageous ; but if iron rose to £12 per ton, it would be necessary to use more timber.

He had been in the habit of assuming the durability of a good rail to be fifteen years ; that an ordinary unprepared sleeper would last six years, and a creosoted sleeper fifteen years : then arose the question of the value of the old materials, and, at the present

prices, he thought those of the longitudinal system were of the least value, next came the transverse system, and the most valuable were those of the saddle-back rail system. Therefore, in England, he should be inclined to adopt the latter; at the same time, in Norway, it had been found more expedient to adopt the longitudinal system, because sleepers cost there only about sixpence each, and for that locality, which offered several peculiarities, it was considered the safest kind of road; and he begged to acknowledge the handsome manner in which Mr. Brunel had supplied him with all the information he required.

Then came the question of the best mode of repairing an existing road; and, from observation and careful inquiry, he had arrived at the conclusion, that the fish-joint was the most effectual system. He was of opinion, that the simple packing of the road could be done, as had been stated, for £40 per mile; but on the question of maintenance of way, generally, the Institution required to be furnished with a considerable amount of data, before the subject could be satisfactorily discussed; and he trusted some Member would supply a comprehensive paper on the subject, in the course of the next Session.

Mr. G. H. PHIPPS said, the statement, of there being, practically, no prejudicial effect from riveting together long lengths of rails, had excited considerable surprise; but, from his own observation, he was prepared to admit the fact of there being no perceptible effect of contraction, or expansion, if the rails were firmly fastened down upon longitudinal bearings; he thought this was as demonstrable by theory as it appeared to be positive in practice.

Mr. HAWKSHAW regretted there had not been more precision in the terms of the discussion. It was just as practicable to define the duration of a rail, as that of a grindstone; it must be evident, that it was dependent on certain considerations; a rail might last any term, between five years and twenty years. The fact was, the life of a rail was in proportion to the number, velocity, and weight of the trains running over the line. He had some rails, weighing 42 lbs. per yard, on the Preston and Wyre Railway, which had been laid twelve, or thirteen years, and now appeared capable of serving for ten years more, whilst, on other lines, he had renewed heavier rails, which had only been laid from three to nine years. When, therefore, the duration of permanent way was mentioned, the nature and amount of the traffic should be specified, or otherwise the conclusions arrived at would be erroneous. The cost of maintenance of permanent way had been referred to, without any statement of the weight and number of the trains, of the expense of the

ballast, of the cost of the iron, or of the precise character of the works.

It was important, also, to consider which system of permanent way offered the least resistance to the passage of trains. He was aware of the difficulty of treating the subject; but it was evident, that a railway might be cheaply laid, and yet, by increased deflection, might offer great resistance, and if it thus augmented the cost of power, there was not much gained by the innovation. A few years ago he had been obliged to take up a piece of railway, which offered less resistance to trains than any line he had yet seen; it was laid by Mr. Hartley, who had attempted to make a line like a lathe bed; the construction was very rigid, the rails were rubbed by hand, into blocks of stone, until a perfectly smooth surface was obtained, and while the line was in working order, it offered only small resistance; but when, partly from its inherent rigidity, it once got out of order, there was no remedy but to take it up and to put down what must be considered to be an inferior road, but which was better adapted to the nature of the traffic.

Captain SIMMONS, R. E., said, that even if, in addition to the gross cost of maintenance of way, the separate expense of each kind of material was given, with all the details that had been mentioned, and all necessary allowances were made, it would still be nearly impossible to arrive at an accurate comparison of the cost of any two lines, on account of the difference in the rolling stock. The weight on the driving-wheels of the engines varied with every class, and the hammering effect of certain kinds of locomotives, must have a very serious effect on the permanent way.

Mr. BRASSEY, in answer to the President, said his experience did not enable him to accord with the statement, that a line could be maintained in effective working condition for £30, or £40 per mile. He admitted that his practice in the maintenance of railways, though extensive, had been confined to lines laid on transverse sleepers, generally with rails of 75 lbs. per yard, chairs of 25 lbs. each, and with iron spikes, and he must state, that he had not been able to find any road which had been more economically maintained, yet he could not have it well done for less than £80 or £90 per mile, and he believed he had not done worse than other contractors, nor had he many idle men in his employ. If he had to construct a railway and to keep it in repair for twenty years, he should use rails of 75 lbs. per yard, on transverse timber sleepers, with 25 lbs. chairs, fastened down with iron spikes, as being less liable to rot than wooden trenails.

Mr. BETHELL, through the Secretary, begged to correct what he

contended was an erroneous statement relative to the inflammability of creosoted timber. During its very extensive use, for upwards of fifteen years, there was only one instance of a structure suffering from fire; and that one was a bridge in Wales, which had been set on fire by a workman driving a red-hot bolt into a creosoted beam.

When Mr. Bethell's premises, at Battersea, were burned down in 1847, the stacks of unprepared timber caught fire long before that which had been creosoted. He conceived the reason for this, to be, that unprepared timber, when heated, gave off a vapour which caught fire at a lower temperature than that at which the vapour from creosoted timber would inflame, because creosote oil required a high temperature to volatilize it. Therefore he contended, that creosoted timber would not catch fire so soon as unprepared wood; but he admitted that when once it was on fire it burned for a longer time.

There was not any instance on record of any of the stacks of creosoted sleepers catching fire, although they were generally placed close beside the railways, and were constantly exposed to the falling upon them of red-hot cinders and sparks from the locomotive engines.

With respect to the duration of prepared sleepers, it was now an accepted fact, that if carefully creosoted, they would endure for at least twenty years; and as regarded the price, the general estimate of 5s. per intermediate sleeper, and of 10s. per joint sleeper, had proved to be rather over than under the actual contract prices.

Mr. R. STEPHENSON, V.P., said the subject under discussion had occupied his attention for many years, and he had some time ago arrived at the conclusion, that the maintenance of permanent way was, as nearly as possible, an insoluble problem, unless by first carefully analyzing every element by which it was influenced; and even then, as those elements were inconstant, and as no two cases could be found exactly parallel, it was evident, that no correct comparison of cost could be arrived at. He quite agreed, that if the traffic was small and the speed slow, stone blocks sufficed for a railway for the conveyance of heavy minerals, at a speed of about ten, or twelve miles per hour, indeed he thought that a stone-block road offered less resistance than a timber-sleeper line.

With these slow trains resistance was a very important object, because by its diminution, an engine of a given power, was enabled to drag after it ten tons, or twenty tons, in addition to the ordinary load; but when it was necessary to convert the power of the engine into velocity, the case was entirely changed, and then that kind of permanent way, best adapted to resist repeated shocks, with the least

injury to the rolling stock, became necessary, and under these circumstances the stone blocks made the worst road.

Even if it was admitted, for the sake of argument, that there was a little more resistance with one system than with the other, it became of little importance, as at high velocities the question of atmospheric resistance came into consideration, and that was entirely apart from the present question. He could not suppose the remarks had intended to imply, that any ordinary difference in the construction of a line could cause any material difference in the resistance of trains. At the time of the discussion on that subject, a wide difference of opinion was entertained by men of experience, but that had nothing to do with the present question. Therefore the distinction he drew was, that on a mineral road, with moderate speeds, stone blocks could be safely applied; but with the high speeds required by passenger traffic, they were quite out of the question; he conceived that his position was proved by the result of the experiment tried by Mr. Hartley, who in constructing a very rigid unyielding line, as nearly as possible resembling a lathe bed, had only produced a perfect block road, which was soon proved to be unfitted for traffic at a great velocity. The cost of maintenance of way must depend, in a great degree, upon the nature of the strata, and the character of the country, through which the line passed; one cutting would keep the men continually employed in repairs, whilst in another cutting, the grass would grow even beneath the rails; the former being in a wet clay, with sand, and the latter in a dry, firm, sandy soil, without any water near it. The simple introduction of a little water, which would be found to vary in all localities, made all the difference; so that if the costs of maintenance of each railway were separately analyzed, it would be found, that instead of being able to compare one line with another of the same length, it would scarcely be possible to compare two miles of the same line. It was therefore a problem, which, at present, could not be solved. He did not wish to be understood as decrying the value of a record of actual facts; on the contrary, it would be highly useful, as if all the circumstances and considerations were clearly stated, an approximate judgment might be formed. But it required great care in ascertaining whether the cases, to which the facts were applied, involved the same facts to the same extent. The question was one of great importance to the railway world, and he hoped the Institution would continue to receive, from resident engineers on railways, the results of the cost of maintaining permanent way, and that the papers would clearly define what was comprehended under the head of maintenance.

It was imperative to arrest the impression, which was entertained by some persons, that it was desirable to obtain a perfectly rigid road; Mr. Stephenson's experience had led to exactly the opposite conclusion. It was quite true, that a rigid road might, theoretically speaking, be considered the best, but in practice it was the worst, for although from its rigidity it might offer the least resistance, it increased the wear and tear prodigiously. His attention had been called, some years ago, to the fact of the rails in the Watford Heath cutting, on the London and North Western Railway, being split and crushed, to such an extent, that although the cutting was through gravel, the rails were removed two, or three times. On a personal examination of the spot, he soon perceived that the destruction of the iron, arose entirely from the gravel having been extremely well consolidated, and the stone blocks so firmly bedded and packed, that the line was rigidly unyielding, and consequently the iron rails were literally crushed under the fast traffic.

The chief causes of deterioration of the permanent way, were the mileage, the speed, and the weight of the trains passing over the line; though the weight *per se* of the engines and its distribution upon the wheels, must also be considered. Wear and tear was, then, entirely a question of certain weights passing along the rails, at given speed; in a given time; the destruction of the surface being accelerated nearly as the speed, and the general dilapidation being augmented in an increasing ratio, as the number and the weight of the trains were increased beyond a given point.

Mr. Stephenson trusted, that the question of 'permanent way' was only opened by the present paper, as it was one of vital importance and could not be too frequently brought before the Institution of Civil Engineers.

February 17, 1852.

JAMES MEADOWS RENDEL, President, in the Chair,

and February 24, 1852.

ROBERT STEPHENSON, M.P., Vice-President, in the Chair.

THE discussion upon the paper, No. 866:—"The Construction and Duration of the Permanent Way of Railways, and the modifications most suitable to Egypt, India, &c.," by Mr. W. B. Adams—being renewed, was extended to such a length, as to preclude the reading of any communication on either evening.

March 2, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

THE following candidates were balloted for and duly elected :—
James Beatty, Samuel Downing, Robert Garrett, John Vaughan,
John Whichcord, and Captain Whitty, as Associates.

No. 867. "The Electric Telegraph; its History, Theory, and
Practical Applications." By CHARLES COLES ADLEY.¹

PERHAPS there is no career of persevering and arduous pursuit, in which the efforts of man to progress are more prominently displayed, than in the improvement of the means of accelerating intercourse between distant places. In the primitive ages the blowing of trumpets, the beating of drums, and the flame of beacon fires, were the only available methods of rapidly communicating signals. Among the Greeks, fire-signals were employed to spread abroad the result of ten years' struggle—the conquest of Troy. The Romans not only used the same kind of signals in Italy, but wherever their power was extended the towers left by them marked their peculiar use. The Scottish border beacons, in comparatively modern times, formed, by their number and position, a telegraphic communication with Edinburgh, and an enactment of the Scottish Parliament in 1455, c. 48, directs, that one bale, or blazing faggot, shall be the warning of the approach of the English in any matter; two bales that they are "coming indeed;" and four bales that they are "coming in great force."

The allusion by Sir Walter Scott, in his poems, to the "fiery cross," must be in the remembrance of all.

At the period of the threatened invasion of England, at the latter part of the last century, fire was made the messenger of news; and even at the present day, from the reflector on the lighthouse top, it warns the mariner on the trackless ocean. But gradually the blazing beacon gave way to corps of runners and of armed horsemen. Then followed the mail-coach, and the carrier-pigeon, to be in their turn superseded by the semaphore, the swift railway train, and swifter express-engine. Here the limit of human possibility appeared to have been attained; yet scarcely had breathing time been allowed, when the world was startled by the introduction of that most wonderful of all the gifts of science and art, the electric telegraph.

¹ The discussion on this paper, and on the communication, by Mr. Window, on the same subject, was continued over portions of three evenings, but an abstract of the whole is given consecutively.

Before entering on a detailed notice of this useful agent, it will be interesting to take a rapid survey of the various means of telegraphing, suggested and employed prior to its introduction.

The employment of magnetism appears to have been thought of as early as the sixteenth century. The Jesuit, Famiano Strada, Professor of Rhetoric at Rome, states, in his "*Prolusiones Academicæ*,"¹ published in the year 1617, that Cardinal Bembo, who died at Rome in 1547, was possessed of a plan for corresponding at long distances, by magnetic agency.²

The Marquis of Worcester, in his "*Century of Inventions*," published in the year 1663, alludes to a method he had discovered, "by which a man could hold discourse with another at a window, as far as the eye can discern black from white." The means intended to be employed are not given, but most probably a kind of semaphore was intended.

In 1684, Dr. Hooke proposed, in a paper to the Royal Society, to employ "masts and yards" for telegraphs; but his project was not noticed.

Afterwards, came Guillaume Amontons, a Frenchman, who, in the year 1690, invented a telegraph available for practical purposes, and proposed to send messages to great distances, such as from Paris to Marseilles, in the then incredible short space of from three to four hours. The secret of his plan consisted in placing in a series of consecutive stations, persons, who by means of telescopes, having perceived certain signals at the preceding station, transmitted them to the next, and so on in succession to their destination. Each different signal corresponded to a letter of the alphabet, the key to which should be known only at Paris and Marseilles. This proposal was really the foundation of the modern semaphore.

Then followed Marcel, whose plans met with a worse fate than those of his predecessors, for, weary with attendance on a dilatory government, he broke his machine, burnt his drawings, and died without revealing his secret. About the same period appeared Linguet, who, during an imprisonment of many years in the Bastille, invented and matured a telegraph, which he offered to construct in exchange for his liberty; but there is no account of his offer having been accepted. Others also took up the subject; but their propositions, meeting with no encouragement, were abandoned.

¹ Lib. I., Prol. II.

² Famianus Strada refers to Cardinal Bembo, as having mentioned a notion of holding correspondence by the occult sympathy of two needles; a notion, at that time, very prevalent, and alluded to, among others, by Galileo and by Sir Thomas Browne.—EDITOR.

Towards the close of the last century, however, Claude Chappe conceived a design for communicating with his two brothers, (who were stationed at some distance from him in the same town,) by means of moveable arms to a pole; and this plan, being subsequently brought before the notice of the Legislature, produced the modern semaphore.

This invention was speedily adopted throughout France, and extended to about fifteen hundred miles, numbering five hundred and nineteen stations, maintained at an annual outlay of a million francs, or about £40,000.¹

This new mode of correspondence was soon adopted by the other Governments of Europe, and numerous forms of apparatus were invented.

The semaphore telegraph was introduced into England in 1796, when the first line was established between London and Dover, and was afterwards extended to Portsmouth. The plan adopted was a vertical mast, with moveable arms capable of being placed in forty-eight different positions. The cost of maintenance of the line between London and Portsmouth, a distance of seventy-two miles, varied from £3,000 to £3,500 per annum. From frequent interruptions by fogs and gloomy weather, it was only available during one-fifth of the year, and the inefficiency, attendant with the expense, caused its abandonment in 1847. The only semaphore line now existing in England is that between Liverpool and Holyhead.

Proceeding in historical order, the electric telegraph next claims attention.

The electric telegraph has its origin in the combination of three separate, yet correlative, physical forces, viz., electricity, galvanism, and magnetism.

Passing rapidly over the early history of electricity, which is parallel with the age of conjecture, the dreamy age of alchemy and the dawn of philosophy, it is necessary to notice cursorily the ob-

¹ The following table shows the chronology of the various primitive telegraphs, and the principles employed:—

Inventor.	Date.	Plan.
Marquis of Worcester .	1663	Unknown.
Robert Hooke . . .	1684	Masts and yards.
Guillaume Amontons .	1690	Signals and telescopes.
Marcel	1700?	Unknown.
Linguet	„	Ditto.
Chappe	1793	Semaphore.

ervation by Thales (B.C. 600) of the attractive power of amber when rubbed ;—the notice by Theophrastus, Pliny, Seneca, Cæsar, Livy and other ancient writers of the luminous appearance attending the friction of certain bodies ; as also of the electrical appearances under certain states of the atmosphere ;—the electrical effects of the torpedo were not unnoticed by Galen, Oppian and Aristotle ; the Chinese are stated to have been, from a very remote period, acquainted with the properties of the magnet, which was termed by them “the directing stone ;”—from the evidence of a MS. poem, “Le Bible Guyot,” written in the thirteenth century, and preserved in the Royal Library, at Paris, the mariners’ compass appears to have been understood, as early as in the twelfth century ;—it is mentioned by Cardinal Vitri, in the year 1200, as indispensable to mariners ;—Dr. Gilbert’s treatise “De Magnete,” in 1600, was nearly the first attempt to classify the science of electricity ; Barlow’s treatise on magnetism followed close on this ; Boyle, a century later, extended Gilbert’s discoveries, and the famous Otto Guericke constructed the first electric machine.

In 1729, Grey and Wheeler found that all bodies might be classified as conductors and non-conductors, and conceiving that conduction might take place through long distances, they succeeded in transmitting a discharge through 800 feet of packthread. Du Fay found that wetting the packthread increased its conducting power.

Soon after the discovery of the Leyden jar, by some German philosophers, Dr. Watson, bishop of Llandaff, in a series of experiments made on Shooter’s-hill, showed that electrical discharges could be transmitted through a distance exceeding four miles, without any appreciable loss of time ; although a great portion of the circuit was formed of land and water. In less than two years afterwards, Winkler, at Leipsic, discharged Leyden jars through very long circuits, of which the river formed a part ; and Le Monnier, at Paris, produced shocks through 12,789 feet of wire. The success attending these experiments suggested the idea of employing statical electricity, for telegraphic purposes.

The history of the electric telegraph is divisible into two distinct eras. The first era comprises all telegraphs in which statical electricity, or electricity produced by friction, was the exciting agent. The second era comprehends all telegraphs in which dynamic electricity, or electricity produced by chemical affinity, is the acting principle. These telegraphs are shown in the following tables :—

ERA I.

CHRONOLOGICAL TABLE OF ELECTROSTATIC TELEGRAPHS.

Inventor.	Date.	Plan proposed.
Odier	1773	Unknown.
Lesage	1774	Pith balls, 24 wires, Leyden jar.
Lomond	1787	Ditto, 1 wire, ditto.
Betancourt	1787	Leyden jar.
Reisen	1794	Ditto, illuminated letters.
Cavallo	1795	Ditto, detonations, &c.
Salva	1796	Ditto.
Ronalds. . . .	1816	Ditto, revolving disc, &c.
Dyar	1826	Chemical decomposition by sparks.

ERA II.

CHRONOLOGICAL TABLE OF ELECTRODYNAMIC TELEGRAPHS.

Inventor.	Date.	Plan.
Sömmerring . . .	1811	Voltaic battery, decomposition of water.
Schweiger	1812	Ditto, improvements on Sömmerring.
Wedgewood . . .	1813	Ditto, for writing.
Coxe	1816	Ditto, decomposition of water.
Ampère	1820	Ditto, 35 magnetic needles & 35 wires.
Schilling	1832	Ditto, 5 needles, 6 wires, and alarms.
Gauss and Weber .	1834	Magneto-electric induction.
Wheatstone . . .	1837	Voltaic battery, 6 wires, and 5 needles.
Alexander	(Mar. 1) 1837	Ditto, 31 wires, and 30 needles.
Steinheil	(Apr. 22) 1837	Magneto-electric machine and 2 needles.
Morse	(July) 1837	Electro-magnetic registering, by voltaic battery.
O'Shaughnessy . .	(Oct.) 1839	One wire system,—earth circuit,—induction machine, and subaqueous wire. .

The first notice on record is that of Odier, who gives, in a letter dated 1773, the idea of an electric telegraph, which should "enable the inhabitants of Europe to converse with the Emperor of Mogul." He states, however, that he formed the idea from a word overheard at a party where Franklin, Priestley, and other great men were present.

In 1774, Lesage, at Geneva, constructed an electric telegraph composed of twenty-four wires, between two rooms. On exciting an electric machine, and joining it to one of the wires, the pith-ball of an electrometer belonging to it was repelled, and the motion signified a letter of the alphabet, or other conventional signal. His plan was submitted to Frederic of Prussia, but it was never carried into execution.

In 1787, Lomond considerably improved upon the plan of Lesage by reducing his twenty-four wires to one.¹

Shortly after Betancourt made some experiments in Spain, on transmitting signals by electricity. It is said that he passed discharges from Leyden jars, through a wire extending between Aranjuez and Madrid, a distance of twenty-five miles.

A plan for telegraphing by illuminated letters was proposed by Reisen, in Germany, in 1794. Small strips of tin-foil in the shape of the letters of the alphabet were arranged at short distances apart on squares of glass. When a discharge was sent, the desired letter became visible in a brilliant succession of sparks.

Cavalló, in his "*Traité d'Electricité*," published in 1795, proposed to employ the Leyden jar, for exploding detonating, or combustible substances, such as powder, phosphorus, &c., in order to attract the attention of the correspondent.

In the following year, 1796, Salva described, before the Academy of Sciences of Madrid, an application of electricity to the telegraph.

One of the most ingenious apparatus for telegraphing by statical electricity, was that invented by Ronalds, in the year 1815, published in his book in 1823, in which he employed an insulated wire, coiled in a frame, for a length of about eight miles, with an alphabetical disc, moved by clock-work, at each end. It was, however, found impossible to obtain an absolute isochronous motion between the two clocks, and the plan did not succeed.

In the year 1826, the first registering telegraph is stated to have been constructed by Mr. H. G. Dyar, of Long Island, U. S. America. He "used the decomposing power of the spark, acting upon a fillet of paper, moistened and stained with litmus, and moved by hand, or by clock-work. The passage of each spark, from a conductor to the paper, produced a discolouration, and by the different combinations of marks thus made, any signal could be transmitted and registered." This is the principle of one of the present printing telegraphs.

This concludes the electrostatic, or first era in the history of the telegraph, during which none of the plans were ever brought into practical operation.

The second, or electrodynamic era, commenced under more promising auspices; it dates from the year 1800, when Volta made the discovery of the pile which now bears his name.

The distinctive feature of Voltaic, or dynamic electricity, as contrasted with statical electricity is, that it is without tension, *i. e.*,

¹ Vide Arthur Young's "Travels in France," vol. i., p. 212.

without any tendency to fly off from the conductors through which it passes. A still further distinguishing characteristic is, that it flows in a continuous stream, while statical electricity darts along in sudden flashes, or gushes. The peculiar adaptation which these qualities give to Voltaic electricity, for the purpose of the telegraph, will be at once apparent.

Sömmerring appears to have produced the first electrodynamic telegraph. In the year 1811, he read before the Academy of Sciences, of Munich, a plan of a telegraph, based on employing, as the means of indication, the decomposition of water by a battery. He used thirty-five wires, which signified the twenty-five letters of the alphabet and the ten numerals. He also tried to prove the velocity of electricity, but was only able to deduce, that it was greater than that of sound, and adds that it would be interesting to know its ratio as compared with that of light, a problem since solved by Professor Wheatstone.¹ Subsequently, Sömmerring is said to have employed the disengagement of the gases, for sounding alarums.

Soon after, Schweiger suggested several important improvements in Sömmerring's telegraph, and proposed a considerable diminution in the number of signals, by employing two batteries of different powers, and reduced the number of wires to two.

About the same time, between the years 1813 and 1817, the late Mr. Wedgewood, on several occasions, laid before the Government a system for writing at distant places by means of electricity, but the exact plans have not transpired.

Professor Coxe, of Philadelphia, in the year 1810, proposed a decomposing apparatus, similar to that of Sömmerring, and confidently predicted the future success of the electric telegraph.

In the year 1819, the late Professor Oersted gave the great impetus to the science of electro-magnetism, by discovering that when a magnetic needle was placed above, or below a wire, and a current was passed through the wire, the needle had a tendency to place itself at right angles to the wire. Schweiger soon improved upon this discovery and found, that by taking a silk-covered copper wire and coiling it round several times, the deflections of a magnetic needle suspended about it, became extremely sensible. Fechner conceived the idea of adapting Oersted's discovery to telegraphic purposes, but was forestalled by Ampère, who, on the 2nd October 1820, read before the Academy of Sciences a description of an electric telegraph on this principle.

¹ Professor Wheatstone's experiments showed, that the electric shock travelled through a copper wire with a velocity, greater than that of light through the planetary space.—EDITOR.

[1851-52.]

About this period Arago observed the magnetic properties of the electric current, and discovered the attractive power of soft iron; while Sturgeon, in 1825, constructed the electro-magnet, and noticed the increased power to be obtained from it.

From this time, the practicability of the electric telegraph became a subject of frequent discussion among philosophers.

M. Amyot relates, that in 1832, or 1833, the Baron de Schilling, of St. Petersburg, constructed an electric telegraph consisting of five magnetic needles, placed in the centre of coils, or multipliers, and set in motion by keys.

All the elements of the electric telegraph were now complete. The battery, the magnetic needle, the coil, or multiplier, and the electro-magnet. A master mind was only wanting to combine the discoveries of Volta, Oersted, Arago, Sturgeon, and Faraday, to produce an instrument capable of supplying the long-sought desideratum. The climax of telegraphic invention at last approached, and no less than four names stand enrolled on the annals of the year 1837 as claimants for this honour. These are Wheatstone, Alexander, Steinheil, and Morse.

There can be no question, however, of Wheatstone's priority in date over Alexander, and Morse. Steinheil had repeated Gauss' and Weber's experiments before that date, but he did not produce any invention of his own until long subsequently.

On March 1st, 1837, Prof. Wheatstone's discovery was announced in the Magazine of Useful Science.

In April, 1837, Mr. Alexander, of Edinburgh, lodged a caveat, for Great Britain and Ireland, for his telegraph, the original model of which, as first exhibited at the Adelaide Gallery, was shown in the Telegraph Department of the Great Exhibition.¹ "His telegraph consisted of thirty-one wires and thirty magnetic needles, each carrying a screen which concealed a letter, for the purpose of showing, upon a distant dial, a series of thirty signals, comprising the alphabet in full, with stops, &c.

On the 12th June, 1837, Messrs. Wheatstone and Cooke sealed their first patent "for improvements in giving signals and sounding alarms, in distant places, by means of electric currents transmitted through metallic circuits." This telegraph, which originally consisted of five needles, has been so often described,² that it is unnecessary to do more than allude to it here.

¹ Vide Catalogue of Great Exhibition 1851, Vol. i., page 455.

² Vide Professor Wheatstone's Evidence before the Parliamentary Committee on Railways.

The five needles were soon afterwards reduced to two, and five other patents were taken out by the same gentlemen, either individually, or in co-operation, for various improvements on the original plan.

In the month of July, of the same year, M. Steinheil, of Munich made an electric telegraph, consisting of magnetic needles and coils of very fine insulated copper wire. The signals were obtained by deflections of the magnetic needles, caused by the action of a magneto-electric machine. Steinheil's instruments were very complicated; he employed the earth to complete the circuit.¹

Professor Morse, of America, also patented, in the same year, an electro-magnetic registering telegraph, employing only one wire, and consisting of an electro-magnet, the coiled wire of which forms the continuation of the line-wire. The armature of this magnet is attached to the end of a small lever, carrying a steel point at its opposite extremity. Under this point is a roll of paper, set in motion by the aid of wheel-work. When a current is transmitted, the magnet attracts the armature which causes the pen to press against the paper. If the contact is rapidly made and broken by the finger-key, simple dots only are made. If the circuit is kept closed for some time, the pen traces a line, proportional in length to the time the circuit remains closed. If no current is transmitted, for some time, the paper exposes a blank surface. The combination of these points, lines, and blank spaces form a symbolic alphabet.

In the Journal of the Asiatic Society of Bengal, for September 1839, is a very interesting account, by Dr. O'Shaughnessy, of a series of results obtained by him in May 1839, on a line of wires of twenty-one miles in length, suspended on bamboo poles. In that paper the one-wire system—the earth-circuit,—the use of the induction machine, and the traversing of rivers by means of insulated wires, were prominently set forth and accurately described, and the importance of the introduction of the electric telegraph in India is strongly urged.²

Above thirty patents have been taken by various inventors in England, for different modifications of the original simple principles

¹ Vide Theory of the Earth-circuit, pp. 323 and 326.

In the year 1803, soon after the invention of the Voltaic pile, experiments were made simultaneously, though independently, by Erman, Bosse, and Aldini, on the principle of the 'earth-circuit.' Vide Minutes of Proceedings Inst. C.E., 1843, Vol. ii., page 182.—EDITOR.

² Dr. O'Shaughnessy has since been intrusted with the construction of the first great Telegraph line in India.—EDITOR.

of the electric telegraph. An abstract classification of their contents is attempted, in the following table:—

CLASSIFIED LIST OF ELECTRIC TELEGRAPH PATENTS.

Date.	For Telegraphs, &c.	For Batteries.	For Insulation, or Suspension of Wires.
1837	Cooke and Wheatstone		
1838	Davy		
1838	Cooke		
1840	Wheatstone and Cooke		
1841	Wheatstone		
1841	Bain		
1842	Cooke	. .	Cooke.
1843	Bain		
1844	Highton		
1845	Wheatstone and Cooke	. .	Wheatstone and Cooke.
1845	Bain		
1845	Brett		
1846	Highton		
1846	Mapple	. . .	Mapple.
1846	Poole	. . .	Poole.
1846	Bain		
1846	Gamble and Nott		
1847	Brett and Little		
1847	Mapple, Brown, & Mapple		
1847	Ward		
1847	Dujardin		
1847	Reid	. .	Reid.
1847	Petrie		
1847	Hatcher		
1848	Highton	Highton	Highton.
1848	Brett		
1848	Barlow and Forster	. .	Barlow and Forster.
1848	Henley and Forster	. .	Henley and Forster.
1848	Bakewell		
1848		. .	Ricardo.
1849	Pulvermacher	Pulvermacher	
1849	Hatcher		
1850	Highton	Highton	Highton.
1850	Brown and Williams		
1850	Bright		
1850	Siemens		
1851		. .	Clark.
1851	Dering		
1851		. .	M'Nair.
1851		. .	Chatterton.

It would extend this paper to too great a length, to attempt even a succinct description of the various forms of telegraphs, contained in the foregoing patents. They may, therefore, be passed over with mere reference to the above list, especially as the chief object of this paper is, to consider the theory and practice of the system, as at present actually developed.

In proceeding to investigate the theory and practice of the electric

telegraph, it will be necessary to discuss it under the following heads:—

SECTION I.

1. The theoretic principles.
2. The materials employed.
3. The deranging causes and practical difficulties.

SECTION II.

4. The laws which govern the action of the electric telegraph.
5. The theory of the mode of transmission of the electric fluid, and of the "earth circuit."
6. The practical applications and concluding remarks.

SECTION I.

1. THE THEORETIC PRINCIPLES.

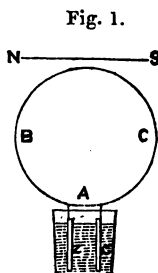
The elementary principles of the electric telegraph are based on the following fundamental axioms:—

Axiom I. A circle of conducting matter is indispensable for the generation and transmission of voltaic electricity.

Axiom II. A triad, or combination of three elements; *i. e.*, two different metals and one liquid, or two different liquids and one metal, is essential for the development of the two electricities, and the production of positive and negative effects.

Axiom III. The property of electricity for transmitting itself through insulated conducting circuits, to very great distances, within very short periods of time.

If in a conducting circle, say of iron wire, as A B C (Fig. 1), a magnetic needle, N' S be placed in juxtaposition to a portion of it while a current is passing, it is subject to the deflections shown in the following table:—



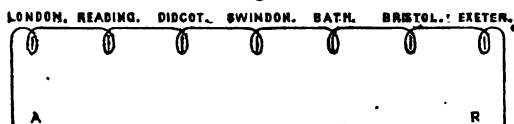
Needle over Wire.		Needle under Wire.	
Direction of Current.	Deflections.	Direction of Current.	Deflections.
South to North	N. Pole to right. S. Pole to left.	South to North	N. Pole to left. S. Pole to right.
North to South	N. Pole to left. S. Pole to right.	North to South	N. Pole to right. S. Pole to left.

It will appear, from this table, that a current flowing both above and below a needle, if in opposite directions, will deflect the needle in the same direction. Hence it follows, that if a magnetic needle, $N S$, be suspended in the centre of a bent wire, passing both above and below it, and the two ends of the wire be joined to the poles of a voltaic couple, the needle will be deflected with twice the power it was before. Here then is obtained the first principle of the electric telegraph, viz., the deflection of a magnetic needle in two opposite directions, when placed in a coil of wire, through which an electric current is passing.

It is evident, therefore, that if the number of turns of the wire be multiplied, so as to represent as many additional currents, and the number of the zinc and copper plates be also multiplied, so as to produce an additional power, the needle will be deflected to a more powerful extent, and such deflection will increase in direct proportion to the number of coils of the wire, and the number of zinc and copper couplets employed.

Suppose again, a wire circle, at several points of which are interposed a needle, coil, and battery¹ (Fig. 2), and handles fixed between the coil and battery, at all the places, in such a manner, that, when

Fig. 2.



in a position of rest, the circuit is closed and no current is transmitted; but when either of the handles is turned to the right, or the left, the battery is interposed in the circuit, and positive, or negative currents are set free; then it will be found, that when the handle at any one point is moved to the right, or the left, the needles in that, and every other coil, will also be moved simultaneously to the right or the left, as the case may be. Similar corresponding deflections of all the needles will instantaneously take place, when the handle at any of the other points is moved. And these deflections will continue the same, at all distances, subject to certain given laws which will be mentioned.

Further, if the wire of the closed conducting circuit be severed, and the two ends be joined to copper plates buried in the earth, the conducting circuit is equally maintained, since the earth has been found to answer all the purposes for completing the circuit. The needle, coil, and battery at each point being considered as so many

¹ Vide Needle, Coil, and Battery, pp. 313 and 314.

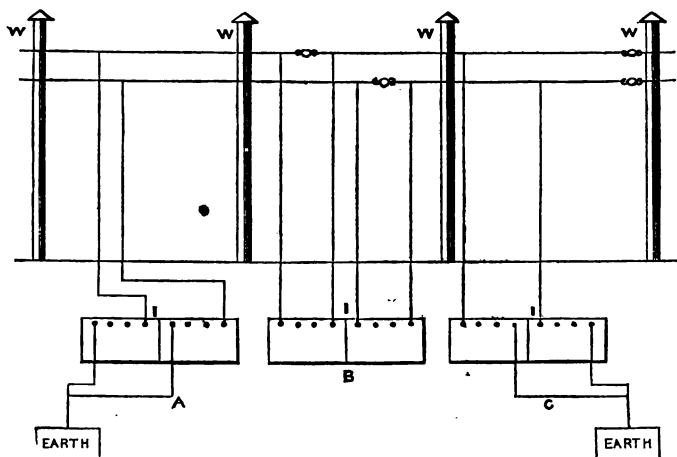
stations, the principle of the electric telegraph will be clearly perceived.

In order to complete the telegraph, it is only necessary to place the needle and coil behind a dial, and to fix the needle on the same axis, with an indicator in front of the dial, so that whenever the needle is made to move, the indicator shall move also. This will give the common single-needle telegraph, the two motions of the needle from the vertical to the right and left being found, when combined, sufficient to produce all the ordinary signals.

When greater speed is required, a double-needle telegraph is employed, which is formed by doubling the needles, coils, handles, and wires throughout the line.

Alarums.—Before commencing a signal, an alarum, or bell is frequently rung from one station, and repeated from the other, in order to call the attention of the parties about to correspond. This is accomplished by a clockwork apparatus, set free by an electro-magnet.

Fig. 3.



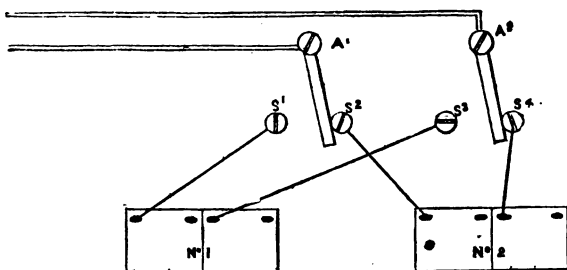
Connection of Instruments.—Suppose A B C (Fig. 3), to be three stations, at which three double-needle instruments, *i. e.*, are required to be connected with the wires, *w w w w*, along the line.

On each of these instruments will be found eight connecting-screws, *i. e.*, four for each of the needles. These eight screws may be marked in various ways, but for convenience-sake they are mostly marked with the letters *L Z C E*, signifying *line, zinc, copper, earth*. The connections are made as they are shown in Fig. 3.

It may be received as a general rule, that in a series of any number of telegraph instruments, connected together in one continuous circuit, the zinc and copper connections remain the same throughout, while the line and earth connections are at one terminal station the reverse of what they are at the other, and at the intermediate stations the earth connections disappear, becoming changed into line-wires.

Triangular system of Duplicates.—In order to secure greater efficiency, and general satisfaction in the manipulation of the electric telegraph, duplicate instruments, bells, and batteries should be kept in good working order at the principal, if not at all the stations, so as to afford immediate assistance, in cases of derangement and disorder; as for instance the duplicate instrument No. 1, in Fig. 4, which may be thrown into circuit, by moving the switches A^1 and A^2 from s^2 and s^4 to s^1 and s^3 respectively.

Fig. 4.



Duplicate bells and duplicate batteries may also be placed at each station, and be connected in a similar manner.

The Galvanometer, or Detector.—The galvanometer, or as it is most generally called, the detector, very much resembles a single-needle instrument, with this difference, however, that instead of the letters for signalling, a scale of degrees is graduated upon the dial-plate. The galvanometer is used for facilitating the detection of a fault in the wire, or elsewhere, and is the most valuable assistant,—in fact, almost the only resource in times of difficulty.

The Resistance-Coils.—The resistance-coils consist of a number of coils containing very thin wire, in different quantities. The construction is based on the principle, that electricity will travel with much greater ease through a thick wire, than through one of less diameter, consequently a few yards of thin wire will oppose a resistance, equivalent to several miles of a wire of greater diameter.

The rheostat may, occasionally, be advantageously employed, in

conjunction with the galvanometer, or detector. Since the effects of the electric fluid are sometimes so deceptive, that it is very difficult to detect whether the error is really at the stations, or along the line.

It would not be possible, within the prescribed limits of this paper, to enumerate the multifarious, and sometimes simple, yet for the time, puzzling causes, which derange the electric telegraph, or to elucidate the various methods of remedying them. An intimate knowledge of this part of the subject can only be acquired by practice and experience, and the numerous contrivances which suggest themselves at the moment, could not be done justice to on paper,—they must be left entirely to the option and practical skill of the superintendent in charge.

2. THE MATERIALS EMPLOYED.

Coils.—The coils used for the telegraph are of various forms and dimensions. Some are elongated and others circular. The elongated, or vertical coils have been as large as $6\frac{1}{2}$ inches in length, 2 inches wide, and $1\frac{1}{2}$ inch thick, wound round with about 300 yards of cotton-covered copper wire, $\frac{1}{100}$ of an inch in diameter. The circular coils vary from $1\frac{1}{2}$ inch to 2 inches diameter, and are covered with a less quantity of silk-covered copper wire, of a less sectional area.

Needles.—The needle originally used was the astatic needle. It consisted of two magnetic needles, $3\frac{1}{2}$ inches in length, joined together by a cross piece about an inch long, with their poles reversed. One of these needles was placed within and the other without the coil, the outer needle serving as the indicator, from which the signals were read. The oscillations produced by so long a needle rendered the instrument ineffective in rapid signalling, and shorter needles, with smaller coils of fine wire were substituted.

Another form, called the compound needle, has been introduced by Mr. Walker, on the South Eastern Railway. It consists of a very thin ivory disc, $1\frac{1}{2}$ inch diameter, sustaining several highly-magnetized short needles, firmly secured on either, or both sides of the disc. This compound needle occupies the place of the inner needle in the coil, and is found to possess some advantages.

Thin horse-shoe magnets have also been employed by Mr. Highton, the magnets being placed within the coil.

The principle of electro-magnetic induction, treated of by Dr. Faraday,—applied by Mr. Wheatstone, to telegraphic purposes in his patent of 1840,—has also been used for telegraphic purposes, by Mr. Highton, and by Mr. Henley. Various other forms of needles, magnets, and coils have also been suggested and tried.

Alarums, or Bells.—The bell consists of an ordinary clockwork apparatus, the escapement of which is set free by an electro-magnet. The electro-magnetic alarum was first patented by Messrs. Wheatstone and Cooke in 1837.

In some cases magneto machines are used in lieu of the Voltaic battery for ringing the bell. The magneto is composed of two coils of wire, placed on the two legs of a powerful horse-shoe magnet, formed of several large magnets screwed together. When the coils are separated from the magnet a current of electricity is produced.

Telegraph Batteries.—The Voltaic battery supplies the motive power for working the electric telegraph, and the simple combination of zinc and copper, excited by dilute sulphuric acid, is the source whence that power is derived.

The batteries, when not too heavily worked, will last from six to twelve months. Some have been known to have worked for six months, continuously, without any addition of acid solution. In this peculiar condition, their intensity does not appear to be in the least diminished, notwithstanding the sand may have become perfectly arid and hard.

Various solutions for exciting the telegraph battery have been tried with varied results.

In America, a form of Grove's battery is used: the number of cells is proportional to the distance to be traversed, about fifty cells being used on a line of two hundred miles.

The greatest length, through which a message has been transmitted, is from Philadelphia to St. Louis, or about one thousand miles. The number of cells used, averaged one for every twenty miles, and from the results obtained, through that distance, it is calculated, that if a wire were made to encompass the periphery of the earth, twelve hundred of Grove's cells would suffice for the galvanic power of the entire line.

Although the batteries, at present used, are well suited for working the electric telegraph, yet they are far from being constant in their action. When worked repeatedly, for any length of time, they speedily run down. The discovery of another battery of more perfect and uniform action, would be a great desideratum, and would create a new era in the history of electric telegraphs.

Suspension and Insulation of Wires.—The wires for suspension along the open line are generally of No. 8 iron wire, $\frac{1}{4}$ of an inch in diameter, and galvanized.

The wires are supported on poles, posts, and standards of red pine, or Memel timber. The lowest wire is generally raised about

8 feet to 12 feet from the ground, except over sidings, level crossings, &c., where it is at a much greater height.

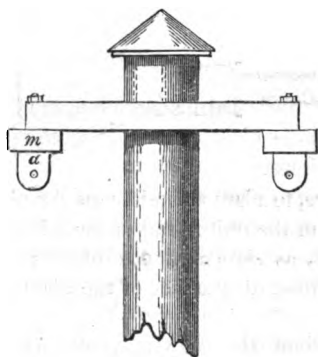
About thirty poles are required for each mile, and the wire is drawn up and secured at each pole; the insulator being made strong enough to sustain the strain of the drawn-up wire. By this means, when a wire breaks, the evil does not reach beyond the two poles adjacent. Mitchell's screws are also used for bracing up the poles subject to heavy strain.

In tunnels and under arches the wires are supported by standards, or brackets, fixed to the masonry.

Insulators.—In order that the electric current may be conveyed, from one end of the line to the other, with the smallest possible amount of leakage at the points of suspension, it is found necessary to insulate the wire, at the poles, standards, &c. This insulation is effected by common brown glazed earthenware. The insulators are made in numerous forms, viz., cones, rings, tubes, double cones, collars, &c., according to the purposes for which they are required.

Notwithstanding the excellent insulating properties of glazed earthenware, the loss from leakage of electricity, along the poles into the earth, in damp, foggy, and rainy weather, was so great, as to detract seriously, from the satisfactory working of the electric telegraph. The mode of insulation, recently introduced by Mr. Edwin Clark, throughout the lines of the Electric Telegraph Company, though it has not altogether remedied the evil, has been found to accomplish its purpose more satisfactorily; a much greater amount of work being now done, by the same, or even by less

Fig. 5.

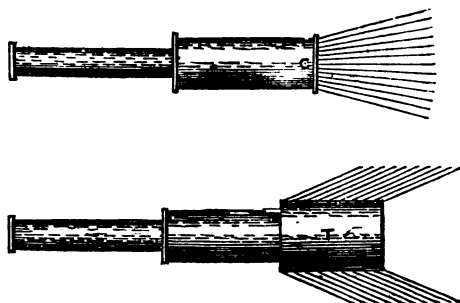


battery power than before. Mr. Clark's insulator consists of a hook of glazed porcelain (*a*) (Fig. 5), surrounded with a zinc cap (*m*);

the wire when hung on to the porcelain hook, being fastened to it with iron binding wire. The insulator is then secured by a nut and screw to an arm, fixed crosswise on the pole. The contrivance is as beautiful in theory as it is found efficient in practice. The insulator being a non-conducting substance and an excellent radiator of heat, always remains at a lower temperature than the surrounding atmosphere, and becomes in fact a condenser. In damp, or foggy weather, the moisture deposits on its surface, and the coke dust, carbonic acid, and sulphur, from the fumes of the engines, flying against it, remain there, and so form a perfect conductor. Now the metal cap, being a conductor and a bad radiator of heat, always retains the temperature of the surrounding atmosphere; thus the radiation of the earthenware is obstructed by the metal cap, and that part of the insulator, which is immediately surrounded by the metal cap, remains dry, and the insulation of the wires is, therefore, almost perfect.

The principle is analogous to that of the night telescope. When a common telescope is used on a dewy night the glass at the object end requires constant wiping, as it becomes obscured by the condensation of the dew upon it, caused by the radiation of the heat from the surface of the glass, as shown at (τ), Fig. 6.

Fig. 6.



In order, therefore, to adapt the telescope for night vision, a sliding metal tube is fixed on the object end of the telescope, and this being drawn out at night, as shown at C , obstructs in a great measure the radiation, and preserves the face of the glass clear, and the vision distinct.

Shackles are used at the drawing-posts, for effecting the better insulation of the wires, and also at the stations, to facilitate the bringing in of the wires. The shackle (Fig. 7) consists of a glazed earthenware ring, furnished with two hooks. These hooks are

insulated from each other, consequently where a shackle is placed the circuit is broken. The shackle very much resembles a pulley in form.

Fig. 7.

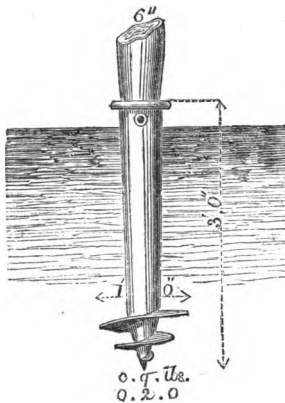


At the drawing-posts the circuit is completed by passing a thin iron wire, or binding wire as it is called, from the outside of the shackle on one side of the post, to the outside of the shackle on the other side. At the stations, this piece of wire is made to pass through the instrument. Sometimes double shackles are used.

Screw Piles.—In order to prevent the injury sometimes arising

Fig. 8.

SCREW FOR ELECTRIC TELEGRAPH POSTS, &c.



from opening ground to insert the supporting poles and for the purpose of greater expedition and economy, Mitchell's screw-pile shoes of cast iron have been frequently employed with very good effect. Indeed Dr. O'Shaughnessy in a series of experiments found them so advantageous for India, that he ordered forty-five thousand screw shoes, which were shipped for that country, and have been most successfully used.

Gutta Percha, and its Value.—Prior to the discovery of gutta percha, and the demonstration by Dr. Faraday, of its excellent insulating properties, many and serious were the difficulties to be overcome in effecting a good insulation of the wires through tunnels. Various plans of insulation for protecting the bare wire were tried,

but all proved fruitless. The abundant percolation of water, the deposit of dust, coke, &c., so deteriorated the insulation, that more electricity was lost in the tunnel than was passed through it. Perhaps the Kilsby Tunnel on the London and North Western Railway, on which the Author was for a long time engaged with Mr. Highton, stands as prominent in presenting difficulties, in this respect, as it is remarkable for the engineering difficulties which had to be overcome in its first construction. There the wires required constantly to be repaired; in fact, they had scarcely been put in than they were found defective, and had to be taken out and replaced by others; and such wires as did remain were found to require renewal after three years, owing to the change they had undergone causing repeated breakage.

The excellent non-conducting properties of gutta percha have afforded a means of overcoming this long-standing obstacle; and copper wires, encased in gutta-percha cylinders about one-eighth of an inch in thickness, or placed in parallel lines within grooved gutta-percha bands, have been successfully employed.

The gutta-percha covered copper wire may either be buried in trenches, or suspended by brackets against the tunnel walls. They may also be placed within two grooved wooden boards, tarred both inside and out, and secured by galvanized iron clips to the sides of the tunnel, the naphtha being extracted from the tar to prevent injury to the gutta percha.

Gutta-percha cells and troughs have also been found very convenient for batteries.

Gutta percha has also been used for insulating the wires in the submarine telegraph between Dover and Calais.

3. REMARKABLE DERANGING CAUSES, AND INVESTIGATIONS AS TO THEIR ORIGIN.

Lightning and Lightning Conductors.—Lightning is, perhaps, the most formidable disturber of the electric telegraph; and from the extent of country which the wires traverse, flashes of lightning are sometimes conveyed into the stations from many miles distant. Sometimes the effects are so slight as not to be worth consideration; but at others the lightning flashes into the stations, fuses the metal-work in its course, demagnetizes the needles, and passes into the earth with a loud report. In some cases the attendant, who has happened to have hold of the instrument handle at the time, has received a violent concussion, and those standing around have experienced electric shocks.

These disastrous effects are in a great measure obviated by means of lightning conductors, an apparatus formed to conduct the light-

ning into the earth before passing through the instrument. There are various ways of accomplishing this. The simplest is to place two sets of metallic points as near as possible to each other, save absolute contact; connecting one set with the line wire before entering into the instrument, and the other set with the earth; the electric fluid will dart off the wires, across the points and into the earth, preferring this shorter path, to the greater resistance opposed to its passage through the coils of thin wire; a very slight but imperceptible portion will however pass through the coils, it being a law of the electric discharge to traverse all paths open to it, in quantities varying inversely as the resistance along those paths.

Among other of the destructive effects of lightning may be mentioned the splitting of the posts during a thunderstorm. To counteract this as much as possible, small metal points, or lightning conductors are fixed to the top of the posts, and are placed in communication with the earth.

Demagnetization of Needles.—Lightning will often demagnetize, or dispel the magnetism of the needles. This more frequently happens in short needles and horse-shoe magnets than in long ones. Other causes also operate in gradually demagnetizing the needles, such as the proximity of a great amount of iron, as, for instance, in an engine-house; the placing of the instruments in stations built of red sandstone, as the quantity of iron oxide contained in the red sandstone extracts the magnetism of the needles, and considerably weakens their action. Hence as little iron as possible ought to be used in a telegraph station.

Action of Needles during the Aurora Borealis.—The needles of the electric telegraph are subject to various deflections during the continuance of the aurora borealis, or northern lights. At such times the needles have a continuous swinging motion to and fro; for a time they are deflected to one side, and then suddenly pass over to the other, and then again they change rapidly from side to side in a few seconds, the intensity of the deflections being so great as to entirely prevent the transmission of messages. At other periods they will have a slow and easy motion, and remain deflected in one direction for several minutes. These deflections have also been known to precede an auroral manifestation.

Periodic disturbances of the Magnetic Needle.—The effective operation of the electric telegraph is obstructed by a variety of other disturbing influences as follows:—

In extensive lines of telegraph the needles are rarely found to coincide with the perpendicular, and are subject to deflections generally not exceeding $\frac{1}{2}^{\circ}$; but on extraordinary occasions varying

from 0° up to 70° . These deflections are so inconstant and uncertain, that as yet it has been impossible to deduce a law from them.

Some observations made on the Continent seem to show, that these deflections are in one direction during the day, and in the other during the night, the variation seeming to take place with the rising and setting of the sun. They also vary with the weather, being less in dry than during rain, and when cloudy and stormy the needles are considerably deflected.

When the sky is densely overcast, with a strong inclination to rain, the needles are influenced by a feeble and varying current, and often, when thick foggy weather prevails, they will hang forcibly over for a quarter of an hour, and then return by degrees. During the prevalence of fogs and a humid atmosphere, especially at the approach of winter, the needles work very sluggishly; this is due in a great measure to the defectiveness of the insulation, caused by the deposition of moisture on the wires.

In very short lengths, especially at tunnels, a gentle vibration and easy deflection are frequently observed, so easy indeed as to be almost mistaken for the needle not being properly balanced.

Moveable Studs and Coils.—The above derangements are in some measure remedied by using moveable studs on the face of the instrument, so that when the needle diverges from the perpendicular, the studs are moved, in order to bring the needle exactly in their centre. Moveable coils are also employed, in order that when the needle declines, it may be restored to the vertical, by moving the coil away from it.

Investigation of the origin of the Periodic and other Disaffections of the Magnetic Needle.—The foregoing disturbances of the magnetic needle may originate in a variety of causes, such as the electric state of the atmosphere, magnetic storms, earth currents, thermo-electric currents and caloric.

Electric state of Atmosphere.—There is no doubt but that the electric state of the atmosphere exerts a corresponding effect on the telegraph wires.

Beccaria made several experiments with extended wires in the air, for the purpose of discovering the electrical conditions of the atmosphere. The wire he generally used was about 132 feet in length, and on one occasion an insulated rope, 1,500 feet in length, was stretched across the river Po, and exhibited intense signs of electricity when a shower was falling. The observations of this assiduous philosopher lasted ten years, and they prove, that the atmosphere is almost constantly electrified, and that its electricity is

usually positive, and has a manifest relation to the state of vapour it contains. The passage of clouds and transition of currents of air from places where clouds were forming, or vapours were falling, affected the indications of the apparatus.

Mr. A. Crosse, of Taunton, has also made some extensive experiments on atmospheric electricity. The wire extended was $\frac{1}{8}$ th of an inch thick, 1,800 feet in length, and was insulated on masts from 100 to 110 feet in height. The results obtained by this zealous electrician prove,—

1st. That in the ordinary state of the atmosphere the electricity is positive.

2nd. During fogs, snow, hail and sleet, the electric state of the wire is altered. It is usually negative when they first appear, then changes to positive, increasing gradually in strength, and then gradually decreasing; changing its quality every three, or four minutes.

3rd. The approach of a charged cloud produces at first, sometimes positive and at other times negative signs; but whatever be the character, the effect gradually increases, then decreases, and disappears, and is followed by the appearance of opposite signs, which gradually extend beyond the former maximum, then decrease, terminate, and are followed by the original electricity. During lightning an explosive stream passes between the balls of the apparatus.

4th. A driving fog, or smart rain frequently electrifies the apparatus, nearly to the same extent as a thunder cloud, and with similar changes.

5th. In cloudy weather, weak positive electricity prevails; if rain falls, it frequently changes to negative, but returns to positive, when the rain ceases.

6th. In clear frosty weather, the positive electricity is stronger than on a fine summer's day, and the intensity is expressed in the descending order, in the following list, commencing with that whose effects are most considerable:—

- a. During the occurrence of regular thunder clouds.
- β. A driving fog, accompanied by small rain.
- γ. A fall of snow, or a brisk hail-storm.
- δ. A smart shower, especially on a hot day.
- ε. Hot weather, succeeding a series of wet days.
- ζ. Wet weather, following a series of dry days.
- η. Clear frosty weather, either night or day.
- θ. Clear warm summer weather.
- ι. A sky obscured by clouds.
- κ. A mackerel-backed, or mottled sky.

[1851–52.]

x

- λ. Sultry weather, the sky covered with light hazy clouds.
- μ. A cold damp night.
- ν. A dry, cold, north-easterly wind.

The results of these experiments corroborate the statement of Beccaria, that the atmosphere is always charged with electricity, and show further, that a larger quantity of electricity is present in winter than in summer. But the most instructive fact, deduced from Mr. Crosse's observations, is the action of the electric wave, if it may be so called. The electricity is weakest during the night, it increases to a maximum at sunrise, and decreases toward the middle of the day. It increases again as the sun declines, and then again diminishing, remains at a minimum throughout the night; clearly proving, that the electricity of the atmosphere is influenced by the same causes which promote an equal distribution of moisture.

The consideration of the foregoing facts will tend to elucidate the origin of some of the causes of the disaffections of the telegraph needle. It is clear, that through the medium of the suspended wire, the electric state of the atmosphere must exercise a proportionate influence on the magnetic needle; but it still remains a problem for solution, whether the atmospheric electricity merely prefers the telegraph wire, to facilitate its passage into the earth, the wires acting as drainers of the superabundant electricity in the air, or whether the atmospheric electricity, present in fogs, rain, &c., does not extract a certain amount of voltaic electricity from the wires, at the same time that it imparts some of its own to them. Probably on the principles of action and reaction, when the electricity in the atmosphere is imparted to the wire in one place, the voltaic electricity in the wire may be extracted in another, some miles distant, to restore the equilibrium, weakening thereby the effect of the battery on the needles. If, however, it can be supposed, that when the electricity of the atmosphere is imparted to the wire and the electricity of the battery is poured into the wire, a conflict takes place between the two antagonistic electricities—the stronger prevailing—then, in fine weather, the needles should work well, from the overpowering superiority of the voltaic electricity, and in dense foggy weather they ought to work sluggishly, (as they do,) owing to the paramount quantity of atmospheric electricity in the wire, resisting the free course of the voltaic electricity.

Magnetic Storms.—There are, besides, other actions which affect the telegraph. There sometimes occur agitations, called magnetic storms, which convulse a whole continent simultaneously, and produce large vibrations of the instruments in the magnetic observatories. Earthquakes and volcanoes are also said to be accompanied

by magnetic disturbances, which cause a permanent alteration of the needle. There is also that influence which produces the diurnal variation of the needle, (something resembling the electric wave,) which seems to follow the course of the sun. It commences, at sunrise, with a westerly sweep, which continues till about 5 P.M. It then retrogrades and continues to move east, until it has reached its mean position, where it settles throughout the night.

Earth Currents.—A third source, whence the disaffections of the needle emanate, is in earth currents, and this happens particularly in short lengths and in tunnels.

Magrini has proved, that if the copper pole of a battery is joined to a long metallic wire, extended in the air, without any communication with the earth, and the zinc pole is joined to another wire, equally extended on the opposite side, without connection with the earth, two constant and vigorous currents, in contrary directions, are generated in the two wires. He has further proved, that the mere connection of a wire, suspended in the air, with a plate buried in the earth, excites in the wire a current, as if the wire played the part of the zinc, in the voltaic couplet.

The author also took an opportunity, during the deflections of the needles, to make some experiments, in order to investigate their origin, and was strongly convinced, that the vibratory motion was due to an earth current, generated between the copper plate buried in the earth, and the iron wire along the line. This, indeed, was only a corroboration of Magrini's experiment, and the results he obtained, tend to show, that if the buried earth were of the same metal as the suspended wire, (and of a surface proportionate to the conducting powers of the metal,) these galvanic actions would in a great measure be obviated.

Thermo-electric Currents.—In tunnels there may be a fourth source, whence these deflections arise. Besides the local action of the earth, a difference in temperature, between the two ends of a tunnel, would cause a current, and it often happens, that one end of a tunnel is wintry and cold, while the other is sunny and warm. Hence a thermo-electric current would be created, and although this may be so slight, as scarcely to be perceptible, yet when added to the earth current, a sensible current of an increased intensity would result.

Caloric.—It must be noticed, however, as a set-off against this, that caloric, or heat, is also a non-conductor of electricity, and setting aside the conflict theory, this alone would explain the occasional sluggish motion of the needles; and it has been observed, that the telegraph needles work much better in a cold, than in an overheated station.

Remarkable Accidents to the Electric Telegraph, &c.—Besides the fusion of the wires in the coils, and the splintering of the posts, by lightning, the telegraph lines are, sometimes, destroyed in a remarkable manner.

On March 28th, 1847, a violent tempest occurred on the Atlantic coast of America. From New Brunswick to Philadelphia, over an extent of more than fifty miles, scarcely any posts were left standing, while the most extraordinary circumstance attending this disaster, was the wires being found coated with a layer of ice an inch in diameter.

On Thursday, April 19th, 1849, a snow-storm considerably damaged the telegraph, on the South Eastern Railway. According to Mr. Walker's account, "the snow adhered to the wires as it fell, until it accumulated to the thickness of a man's arm, forming tolerably regular cylinders, in one continuous length from pole to pole, and what was remarkable, the wires occupied very nearly a central position in these cylinders. The wires were depressed by the weight of the snow, forming four festoons of congealed snow 55 yards in length, and descending within 5 feet, or 6 feet of the ground, from heights of 12 feet and upwards. The wires in some places broke down with the snow, and between Ashford and Hythe, a distance of eight miles, thirty-six poles were broken, besides many more being thrown down." Mr. Weekes, of Sandwich, states, that on the same day, at 2 A.M., tremendous currents of atmospheric electricity were passing between the balls of the atmospheric apparatus, and continued for about three quarters of an hour. The wind blew a perfect hurricane, while sleet descended in vast quantities, accompanied by hail, wind, flashes of lightning, and peals of thunder.

In Austria, about the vicinity of Vienna, frequent shocks were experienced by the workmen, when putting up the wires. These shocks did not cease, until the precaution was taken not to touch the wires with naked hands. On one occasion a workman received a shock so violent, as to overturn him, and to paralyze his right arm.

On 17th August, 1849, at Frielitz, a workman who was engaged on the wires, near the station, during a storm, experienced a shock which turned him over, and burnt his fingers whilst holding the wire. Hence great caution should be exercised in meddling with the wires, during a thunderstorm.

4. AMONG THE LAWS WHICH GOVERN THE ACTION OF THE ELECTRIC TELEGRAPH THE FOLLOWING MAY BE MENTIONED :—

Law I. The deflective power of the needle is in a direct ratio to the force emanating from the battery, the number of convolutions

on the coil, and the sectional area of the wire forming those convolutions, its magnetic intensity, and the area and conducting power of the earth plate. While it is in the inverse ratio to the length and resistance of the wire in the circuit, the number of the points of suspension, and the resistances of disturbing causes.

It may be well to notice, that a short length of thick wire, wound on a coil and used with a strong current, is equivalent to a long length of thin wire, wound an increased number of times on a coil and used with a weak current.

Law II. If the electromotive forces and the resistances of the circuit are increased, in an equal ratio, the force of the current remains the same, or

$$F = \frac{E}{R} = \frac{n E}{n R}$$

whence it follows, that only one Voltaic element, or one battery, composed of any number, whatever, of exactly similar elements, produces the same effect, provided that no additional resistance is placed in the circuit. While if an additional resistance is interposed, the force of the current is diminished, in the inverse proportion to such resistance.

Law III. (α) The electromotive force of a Voltaic current varies as the number of elements and the nature of the metals and of the liquids, which constitute each element, but does not depend, in any way, on the dimensions of their parts.

(β) The resistance of each element is directly proportional to the distance between either of the plates, in the liquid, and the specific resistance of this liquid and inversely proportioned to the surface of the plates in contact with it.

(γ) The resistance of the junction wire, in a circuit, is inversely proportional to the surface of the plates in contact with it. Professor Ohm thus expresses this law :

$$F = \frac{n E}{\frac{n R D}{S} + \frac{r l}{s}}$$

Where F = force of current.

E = electromotive force of one element.

n = number of elements.

R = specific resistance of liquid.

D = breadth of liquid, or distance between the plates.

S = section of plates in contact with the liquid.

r = specific resistance of joining metallic wire.

l = length of ditto.

s = section of ditto.

Theory of the "Earth Circuit."—Great differences of opinion exist, respecting the action of the "earth circuit." It is supposed by some, that the earth acts as a conductor, and thus like the once used "return wire," conducts the electricity back to its starting-point.

Others conceive, that the earth acts as a reservoir, or draining-well, where the negative electricity, on the one side, and the positive, on the other, are sucked in and absorbed. This is doubtless the most correct view, as experiments have proved, that the resistance through a circuit, entirely of wire, is greater than when it is formed partly of metal and partly of earth, and it is well known, that the metals are better conductors than the earths. Professor Gauss conceives the electricity to be generated at the poles of the battery and to be dissipated at the earth-plate.

5. PRACTICAL APPLICATIONS.

The first practical application has already been described, being the means of conveying instantaneous intelligence to distant places.

The second comprises an arrangement, by which a series of clocks are worked together, by an electric current, and it is anticipated, that a greater degree of precision and regularity will be obtained by this method, than in the ordinary way. This application was first described, by Mr. Wheatstone, in a paper communicated to the Royal Society, in November 1840. Greenwich time is now accurately transmitted daily, by the electric telegraph, to various parts of the kingdom.

The third is for facilitating the comparison of two pendulums, *i. e.*, when it is required to compare a standard pendulum with one of different time of vibration. This delicate operation cannot be accomplished, in the ordinary way, without attentively observing the oscillations of the two pendulums, and noticing their coincidence; a method very liable to error. The new plan is, to have the oscillations of the two pendulums indicated by two needles, placed on a dial which is connected with a clockwork apparatus, having an electro-magnet attached to it. Two wires are then suspended at the extremities of the two pendulums, so that when they arrive at the furthest point of their swing, contact is made and broken, which causes a motion in the needles on the dial.

The fourth is an apparatus for registering the indications of the thermometer, barometer, &c., whether elevated in the air, or sunk in the depths of the earth. This consists also of a clockwork apparatus, to which a vertical catch is attached, which catch is connected with a metallic wire, moving in the tube of the thermometer, &c. The wire being made to traverse the graduations of the thermometric scale, every change in the thermometer, &c., is duly

notified. This was invented by Mr. Wheatstone, and communicated by him to the British Association.

The fifth is in blasting and submarine explosions; for where the loss of power would be so great, in conveying a current through a long length of wire, as to render it difficult to produce ignition, a secondary battery, thrown into action by the deflection of a needle, or the attraction of the armature of an electro-magnet may be effectively employed.

The sixth is the adaptation of the electric telegraph to astronomical observations. By this means, the exact time of transit of a star, at any given observation, can be registered, at any other place, to which there is a communication by telegraph, and thus the longitude is obtained with great facility. This was first proposed by Mr. Wheatstone, and announced in the *Bulletins of the Royal Academy of Brussels*, October 1840.¹ Since the establishment of the submarine telegraph, successful observations, of this nature, have been made between Greenwich, Paris, Brussels, and other places. The telegraph has also been applied to registering the time of transit, at any particular observatory.

The seventh is the adaptation to various chronoscopes for measuring extremely short intervals of time, as the flight of bullets, cannon-balls, &c. These are chiefly the inventions of Wheatstone, Pouillet, Constantinoff, Bréguet, and Jacobi.²

Other propositions have also been made, for introducing the telegraph into hotels and large public buildings; also for joining all the fire-engine, and police stations in cities, or large towns, together, to afford more effective assistance in cases of conflagration and danger.³

Such are some of the modifications in the construction of the electric telegraph, and the uses to which it may be applied. It would be difficult, however, to place a limit to its ultimate adaptations.

With regard to the various printing, writing, and letter-showing telegraphs, the limit of their utility may, for the present, be confined to the parlour, or the scientific laboratory.⁴ The present

¹ Vide *Bulletins de l'Académie Royale des Sciences de Bruxelles*, 1840, vol. vii., 2nd part, p. 131.

² The electro-magneto chronoscope was invented by Mr. Wheatstone, and announced in the *Bulletin of the Royal Academy*, for October 1840. The subsequent contrivances of Constantinoff, Bréguet, and Pouillet were introduced as modifications, with a full knowledge of what had been already done.—EDITOR.

³ The system is very completely arranged at Berlin, and also at Philadelphia.—EDITOR.

⁴ The printing telegraph of Morse is very extensively employed in the United States, America.—EDITOR.

needle telegraph is fully adequate to answer the various purposes for which it is required, and perhaps it would be better for inventors to turn their attention towards overcoming some of the practical obstacles, which prevent the more satisfactory working of the electric telegraph, than to producing different and complicated modes of applying a system so simple, and efficient in itself.

The rate of transmitting a message varies from eight to twenty words per minute. When the insulation is good, the average number transmitted is seventeen to eighteen words per minute.

The development of the electric telegraph, within the last ten years, has been, and still continues to be, so astonishingly rapid, that it would be difficult, at any moment, to estimate correctly the extent in actual operation.

At the present time, (1852), the lines of telegraph either made, or making, may be estimated as under; in—

	Miles.
England	4,000
France	1,520
Germany	4,870
Russia	2,030
India	25
America	15,000 ¹
Total	<u>27,445</u>

¹ TELEGRAPHS.—The number of telegraph wires in the United States is 89, the length of telegraph lines is 16,729 miles; the total length of wires is 23,275. The system of magnetic telegraph was introduced into the United States by Mr. S. F. B. Morse, who claims to be the discoverer, or inventor of this mode of transmitting intelligence. He conceived the idea of such a telegraph in 1832, procured a patent, and made the discovery public in 1837. By the aid of the Government a line was established for the trial of the method between Washington and Baltimore, and its success was perfect from the first.

In the United States the wires are supported on masts, or posts of 20, or 30 feet high. The cost of construction is about 150 dollars per mile. Iron wire is now generally used, though copper wire was first adopted. It was found to be too expensive. A message of ten words, or less, can be sent from Washington to Baltimore for 20c.; to Augusta, Maine, 619 miles, for 1 dollar 15c.; to Natchez, Mississippi, 1,694 miles, for 2 dollars 05c. Messages are sometimes sent over a line of 2,000 miles long without being rewritten and without interruption.

Canada is also well supplied with telegraph lines. Their total length is 983 miles. Congress has under consideration a plan to establish a telegraph over the plains to San Francisco, as the precursor of the proposed railroad.—Extracted from *The Times*, April 26th, 1854.—EDITOR.

In the year 1848, there were but six thousand miles in operation ; so that in three years the amount has been nearly quintupled.

The electric telegraph is now extending in all directions, new lines are being constantly opened, and new proofs of its wonderful powers are recorded. The Dover Strait has been successfully crossed, and the continental nations are extending the system, as rapidly as their finances will permit ; the governments of Austria, Prussia, Bavaria, and Saxony, are adopting a general tariff, for messages transmitted throughout their dominions. Russia is contemplating the connexion of its capital on the Baltic, with its ports on the Black Sea, while a still ampler conception presents itself, in which the great lines of Eastern Europe may form but a link in the chain of general telegraphic communication.

However premature, or sanguine, the expression of these views may now appear, one fact is certain ; the electric telegraph is but in its infancy, and will yet become a powerful agent, in promoting the cause of civilization and the preservation of unity, peace and good-will throughout the world.

No. 863.—“On the Electric Telegraph, and the principal improvements in its Construction.” By FREDERICK RICHARD WINDOW, Assoc. Inst. C.E.

THE necessity of a means of communicating intelligence of events happening in any place, to another point at a distance, in a time less than that in which the distance could be travelled, has been felt from the most remote ages ; and even among the earliest records there are instances of contrivances for accomplishing this end, with more, or less certainty and success. To machines and instruments of this kind, has been given the name of “telegraph,” (from *τηλε*, at a distance, *γραφω*, I write).

The first and simplest form of telegraph that suggested itself, as the most readily available, was fire, which from its twofold accompaniment of flame and smoke was an apt signal by night, or by day. Watchfires, in ancient warfare, were always the signals from one troop to another, and to the present day, in Oriental countries, when a person of consequence travels, his advent is always signalled in advance, from hill to hill, by fires kindled on the summits.

That the use of telegraphs was known to the Greeks, there is abundance of evidence to prove ; it may be instanced, that the Greeks believed the taking of Troy to have been telegraphed to Greece by

watchfires. The opening scene of the "Agamemnon" of Æschylus introduces a warder, or watchman, who says :—" and now I am watching for the signal of the beacon, the fiery messenger bringing intelligence from Troy, and the news of its capture !" Polybius gives an account of telegraphic signals to be used in war (which he calls *πυρσφαλαί*, because fire was used as the agent) ; and Æneas, the contemporary of Aristotle, proposed a system of telegraphs, by means of the isochronic escape of water from two vessels. All these methods were, however, necessarily very imperfect, as they involved the necessity of using only arbitrary preconcerted signals, or sentences, the number of which was very restricted, from the few combinations available, and by which it was only possible to communicate foreseen events. They do not seem to have been ever brought into general use : nor does it appear, that the moderns ever possessed such a thing as a telegraph, beyond beacon fires, until 1663, when the Marquis of Worcester announced his discovery of "a method by which intelligence can be conveyed as far as eye can discover black from white, without noise made, or notice taken, and also by night, though dark as pitch be black."

At the end of the seventeenth century, M. Amontons invented a new method of telegraphic correspondence, by means of an imperfect semaphore, established on a chain of stations, from one place to another. In 1763 it was proposed, by Mr. Edgeworth, to correspond by means of a windmill, the position of the arms, and the sails being slipped on, or off, to constitute the signals. But it was not until the French Revolution in 1793, that the telegraph was ever systematically applied to useful purposes, the method employed being the invention of M. Chappe, differing but little, however, from that of M. Amontons. The correspondence was transmitted from the "Comité de Salut Public," at the Louvre, to Lisle, the station of the French army at that period. A description of the machine was taken to Frankfort, where two models of it were made, and presented by Mr. Playfair to the Duke of York. A description of it appeared in the "English Review," of June 1796, and shortly afterwards the Government set up a chain of stations from the Admiralty to the sea-coast. Various improvements in telegraphs were introduced, in quick succession, by scientific men, amongst whom the name of Sir Home Popham is distinguished, and subsequently that of General Pasley, who in 1822, invented the "Universal Telegraph," which has been in general use ever since, till the rapid stride of science overcoming intervening obstacles, it, in its turn, was superseded by the wonders of galvanic electricity.

During the greater part of the last century, the possibility of

transmitting intelligence by means of electricity, was a favourite scheme with philosophers; and many experiments were made, at various times, in furtherance of this idea, of which the following are a few of the most interesting and worthy of notice.

In 1733, Du Fay made some experiments in France, in order to ascertain the distance to which the electric current could be sent; and electric shocks were sent through upwards of four miles of copper wire.

In 1746, Winkler, at Leipzig, passed electric currents through a long wire, part of the river Pleiss being included in the circuit.

In 1748, Dr. Watson suspended two miles of wire upon wooden posts, at Shooter's Hill, and completing the circuit by the earth, sent electrical currents through it. This fact of using, so early as 1748, the earth as the return circuit, is worthy of note; for in the earlier inventions of the present century a separate wire was reserved for this purpose, and it was not until 1838, that Mr. Cooke again suggested, that the earth might be effectually employed.¹

In Arthur Young's "Travels in France," published in 1787, is the following paragraph: "An ingenious mechanic has made a remarkable discovery. You write two, or three words upon paper, he takes it with him into a room, and turns a machine enclosed in a

¹ In describing a pair of electro-magnetic signal telegraphs, for the Aix-la-Chapelle Railway, Professor Wheatstone stated,—“That a large extent of earth, or a portion of a river, could be made to complete an electric circuit, was long since established with respect to electricity of high tension, by the extensive experiments of Dr. Watson, in 1748, and others; and the same thing was proved with regard to voltaic electricity, by the independent experiments of Erman, Basse, and Aldini, made in 1803. Erman's experiments were performed in the river Havel, near Potsdam; those of Basse in the river Weser, and the environs of Hamel; and Aldini's researches were prosecuted on the shore near Calais. Professor Steinheil also employed the earth as a means of completing the circuit, in the electro-magnetic telegraph which he established at Munich in 1838.

“A pair of Professor Wheatstone's telegraphs were established at Berlin in the beginning of 1842: the line of communication was a single wire, carried through the air upon wooden posts, and plates of metal attached to the ends of the wire were buried in the ground. In the same year he formed a communication between King's College and the Shot-tower on the opposite side of the river: the communicating wire was laid along the parapets of Somerset-house and Waterloo-bridge, and thence to the top of the tower, where one of the telegraphs was placed; the wire then descended, and a plate of zinc attached to its extremity was plunged into the mud of the river; a similar plate was attached to the extremity at the north side, and was immersed in the water. The circuit was thus completed by the entire breadth of the Thames, and the telegraphs acted as well as if the circuit was entirely metallic.”—*Vide Minutes of Proceedings Inst. C.E., 1843, vol. xi. p. 181.*—EDITOR.

cylindrical case, at the top of which is an electrometer, and fine pith balls. A wire connects with a similar electrometer, in a distant apartment, and his wife, by remarking the corresponding motions of the balls, writes down the words they indicate, from which it appears he has formed an alphabet of motions. As the length of the wire makes no difference of effect, a correspondence might be carried on at any distance." Thus here is a clear account of a single wire electric telegraph, so early as 1787.

In 1787, a wire twenty-seven miles in length was extended, by Betancourt, between Madrid and Aranjuez, by which shocks from a Leyden jar were transmitted, and pith balls were repelled.

Early in the present century, Sömmering invented a telegraph, consisting of thirty-five wires,—twenty-five for the letters of the alphabet and ten for the numerals,—by which water was decomposed as the signal. This form was, however, too expensive in its construction, to become of any commercial utility.

Shortly afterwards, Ronalds produced a scheme of two rotating dials, moved by clockwork, having the letters painted on them, and one of them only appearing at a time, at a hole in a shade, placed in front of the dial; as the letter which it was intended to indicate, appeared, two pith balls were repelled, by means of electricity. The necessity, however, for exact isochronic rotation proved an unconquerable difficulty, and the idea was abandoned.

There appears here to have been a lapse of some years before any new idea of importance, on this subject, was made public; till in 1820, Ampère first proposed to deflect magnetic needles for telegraphic purposes. This induced the attention of inventors, and the result was, that in 1837 (a remarkable year in the annals of the electric telegraph), four distinct contrivances of this nature were announced almost simultaneously in Edinburgh, Paris, Frankfurt, and Munich; so that it is difficult to decide which of them was the first to attract public attention to the feasibility of establishing, for commercial purposes, a more expeditious method of communication, than that afforded by the old semaphores, or the still more tardy mail.

The following is believed to be a correct statement of the dates, regarding the invention in this country.

In "The Magazine of Popular Science," of March 1st, 1837, is announced the discovery, by Mr. Wheatstone, of an Electro-magnetic Telegraph.¹

¹ In the "Magazine of Popular Science" (published by Parker, London), for March 1st, 1837, the following passage occurs:—

"During the month of June, last year (1836), in a course of lectures,

On the 22nd April 1837, Messrs. Alexander and Hamilton, of Edinburgh, entered a caveat for an invention, for making communications between places at a distance from each other.

In June 1837, Messrs. Wheatstone and Cooke's first patent was sealed.

In "The Scotsman" of August 1837 the possibility of establishing an electric telegraph on Alexander's principle, between London and Edinburgh is discussed; it was proposed to consist of twenty-six insulated copper wires laid in a wooden trough under the turnpike road: the cost was estimated at £100,000.

In September 1837, various journals mentioned the success of Wheatstone and Cooke's electro-magnetic telegraph, established between Camden Town and Euston Square stations, on the North Western Railway.

A model of Mr. Alexander's instrument was exhibited at the Society of Arts, November 22, 1837.

In a very interesting Paper, by Dr. O'Shaughnessy, in "The Journal of the Asiatic Society of Bengal" for September 1839, is an account of some experiments made by him, at Calcutta, in the spring of that year, which clearly show him to be among the first to introduce this invention in a practical manner. It is worthy of notice, that he mentions the conducting power of rivers, and other large tracts of water, and also gives a clear idea of the possibility of submarine telegraphs; having ascertained, by trial, that "an insulated rope may be led through a river, and will still conduct, without any appreciable loss, the electric signals. The telegraphic line upon which these experiments were made was twenty-one miles in length, and consisted of iron wire, suspended on bamboo poles.

delivered at King's College, London, Professor Wheatstone repeated his experiments on the velocity of Electricity, which were published in the Philosophical Transactions for 1834, but with an insulated circuit of copper wire, the length of which was increased to nearly four miles; the thickness of the wire was $\frac{1}{8}$ th of an inch. When machine-electricity was employed, an electrometer placed on any point of the circuit diverged, and wherever the continuity of the circuit was broken, very bright sparks were visible. With a voltaic battery, or with a magneto-electric machine, water was decomposed, the needle of a galvanometer deflected, &c., in the middle of the circuit. But, which has a more direct reference to the subject of our esteemed correspondent's communication from Munich, Professor Wheatstone gave a sketch of the means by which he proposes to convert his apparatus into an electrical telegraph, which, by the aid of a few finger-stops, will instantaneously, and distinctly, convey communications between the most distant points. These experiments are, we understand, still in progress, and the apparatus, as it is at present constructed, is capable of conveying thirty simple signals, which, combined in various manners, will be fully sufficient for the purposes of telegraphic communications."—EDITOR.

It would be tedious to enumerate the many schemes which now claimed the public attention, and which, each in its turn, enjoyed some degree of notoriety; suffice it to say that the first line of electric telegraph laid down for useful purposes was constructed in 1838 upon the Blackwall Railway, the instruments employed being the subject of a patent granted to Messrs. Wheatstone and Cooke, in June 1837.

Having now traced the electric telegraph to the point where it became for the first time, a useful commercial fact, the prosecution and perfection of which is naturally connected with the practice of the engineer, it is intended to quit the form of narrative heretofore employed, and to examine the several parts in their most important details, from the days of its infancy, to the present time, so that by contrasting the past with the present, it may be seen what ingenuity has accomplished in a few years, and also by perceiving the defects in the present system, it may be learnt what still remains to be done.

In the first experiments with electricity, as a power available for telegraphic purposes, the fluid from the electrical machine was employed, and its presence was detected by the repulsion of two pith balls. In 1811 Sömmering employed the galvanic battery as the agent to produce the required electricity, and noted its presence by the decomposition by it of acidulated water. In most of the modern systems of electrical telegraph, however, the signals depend upon the fact discovered in 1819, by Oersted, and subsequently theoretically explained by Professor Faraday, of a magnet possessing a tendency to revolve round a conducting wire, or the pole of another magnet.

In order to render the subject clear it may be well to examine succinctly the theory of the deflection of magnetic needles.

Fig. 1.

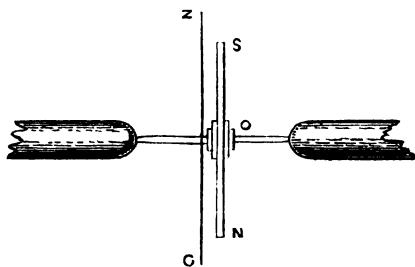


Fig. 2.



Let a magnetic needle NS , (Figs. 1 and 2,) be suspended on an

axle o , passing through its centre, in such a manner that it may revolve freely upon that axis, in the plane ns ; and let over this needle be placed a wire cz , running parallel to it. Now if an electric current be made to pass along this wire in the direction cz , the needle will immediately tend to assume the position shown in Fig 3, the two poles n , and s , of the magnetic needle both

Fig. 3.



Fig. 4.

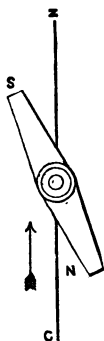
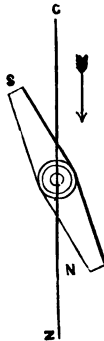


Fig. 5.

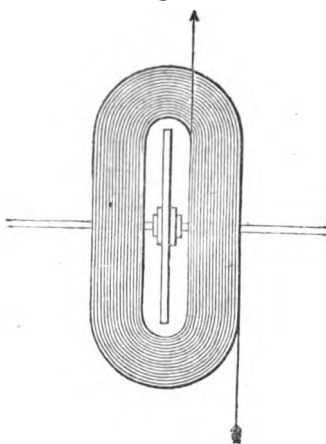


endeavouring to revolve round the conducting wire cz , but in opposite directions; that is to say, the S . pole tends to rotate from left to right under, and from right to left over the conducting wire, and the N . pole from right to left under and from left to right over the same. If the respective positions of the needle and wire, are reversed, the direction of the current remaining the same, but being under, instead of over the magnet, from the same laws, the needle will assume the position represented in Fig. 4; the S . pole having a tendency to rotate from right to left, and the N . pole from left to right over a current in the direction denoted. Thus a magnetic needle suspended with the N . pole downwards is deflected, the S . pole to the right, and the N . pole to the left, by an electric current passing from north to south over it, and in the contrary direction by the same current under it. If the direction of the current be reversed, exactly opposite effects are produced (*see* Fig. 5). Thus it will be seen, that by keeping the relative positions of the conducting wire and the magnetic needle unaltered, and merely changing the direction of the electric current along the former, the direction of the deflection of the latter may be changed at will.

The force of deflection, however, varies directly as the quantity of electricity on the conducting wire, and the amount, capable of being conveyed to any considerable distance, is too small to ma-

terially affect any needle, but such as is too delicately hung for

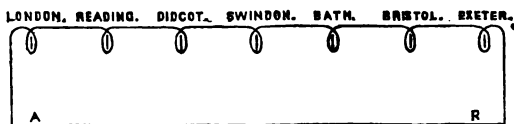
Fig. 6.



practical telegraphic purposes; it is therefore increased, by covering the conducting wire with some insulating substance, such as silk, or cotton, to prevent metallic contact, and then winding it into a coil, as in Fig. 6, and placing the needle inside it. The current is thus sent above the needle in one direction, and returns under it in the other, and consequently, in both cases tends to urge the needle round the same way; and the force of the current in the single wire is multiplied by twice the number of convolutions there are in the coil.

The above description is intended to show, how the presence of electricity along a wire may be detected, and it is also easy to see, that a code of signals can be established by the various combinations of the movements of this needle. It is not necessary that each particular station, or place to be signalled, should have a separate wire, because so long as the circuit is closed, as many coils and needles can be introduced, as may be required; and provided the polarity of all the needles be similar, and the coils all turned in the same direction, the like signals will be repeated in each (Fig. 7).

Fig. 7.



So long as the telegraph is not employed at any particular station, the circuit is carefully kept complete, that other places may correspond, but when a communication is to be made, the circuit is broken and the battery interposed, when a signal is immediately made at every point in the chain of stations; the nature of the signal varying, of course, with the manner in which the battery is connected.

This constitutes the general principle of the present electric telegraph, but to understand properly the practical working, each individual part must be minutely examined in detail; and it is intended,

for that purpose, to run rapidly through the various inventions relative to this branch of engineering, which have been successively brought before the public; or rather such parts of them as introduce anything of practical use, novelty of principle, or superiority over those which preceded them, because the number of such inventions, modifications, and improvements is so great, that to describe them all would carry this paper far beyond the prescribed limits, and would prove tedious, from the repetition it would necessarily involve.

The actual working of the electric telegraph may be divided into three distinct parts, each of them entirely apart from the others, and as such, worthy of separate and individual study. They are—

- 1st. The battery; or the means of obtaining the power by which the whole is worked.
- 2nd. The wires, and their insulation; or the means of conveying that power to the place of its action; and
- 3rd. The instruments; or the methods of using the power so obtained.

It will be seen, that although all these parts are quite independent of each other, yet the whole is dependent on each, for it is impossible that the working of the entire system can be perfect, while any portion remains defective.

ON BATTERIES.

Among the inventors of galvanic batteries, the names of Daniell, Smee, Wollaston, Bunsen, and Grove stand prominent. But their attention has chiefly been turned to the construction of a battery capable of giving out large quantities of electricity. And their inventions, principally made prior to the general introduction of the electric telegraph, were not suited to the economical production of small quantities of electricity of high tension,—continuous, and of uniform strength, which is necessary for the use of electric telegraphs.

It is to be regretted, that this department, the most deserving of study in the system of electric telegraphs, should have been so much neglected by most inventors, who have devoted their time to this branch of engineering; for while their attention has been constantly fixed on producing improvements in the working instruments, which, however clever and ingenious they may be, are sometimes but little available for general practice, the motive power, the widest field for substantial improvement, with very slight modification, has been left in its original expensive, unwieldy, and ineffective form.

In the earlier batteries, the couples of copper and zinc were, as in
[1851-52.]

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ordinary Wollaston's batteries, fastened on to a cross-beam, and plunged into, and raised from troughs containing sulphuric acid and water, by means of a screw. The plates, however, so soon became encrusted with a coat of sulphate of zinc, that all chemical action ceased, and they therefore could only be worked for a very short period without repair. The zinc plates were next enclosed in bladder, or other membrane, and a saturated solution of sulphate of copper was employed as the exciting fluid: this was also found to answer but for a short time, as the membrane became filled with hydrogen gas. A battery was next charged with sand, moistened with dilute sulphuric acid: this acting as a filter, in some degree prevented the deposit of sulphate of zinc upon the plates, and also moderated the action of the acid upon the positive metal. These are the batteries now in general use, for with all their imperfections they are perhaps the best yet produced; they are not costly, and require but little attention.¹ A useful modification was introduced in 1846 by Messrs. Brett and Little. Their battery is constructed with three rows of troughs, the solution being placed in the upper one, and dripped through a small perforation into the second, which contained the sand and plates, whence it drained into the third, carrying the noxious sulphate of zinc with it: the plates are thus free from any coating, and chemical action continues, so long as any solution remains in the upper troughs.

Mr. Highton uses a saturated solution of sulphate of alumina, which he says continues a longer time in action, without the addition of any fresh liquid.

It has also been found, that if a piece of zinc be buried in the earth, at any point, and a piece of copper be also buried at any other distant place, there will be established along a wire connecting the two, a current of electricity, sufficiently energetic to work an ordinary telegraph. The intensity of the current is stated to increase with the distance, but its direction will be constant, according to the position of the two metals.

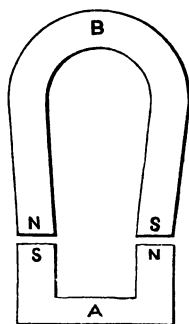
The annual cost of the battery power, required for an average business on a large scale, may be reckoned at about sixteen shillings per mile.

A very valuable method of procuring electricity for these telegraphs, is to make use of the current induced in a wire, or other metallic surface coiled round a piece of soft iron, at the moment

¹ These batteries are now being gradually superseded in the Electric Telegraph Company, by a modification of Daniell's constant battery, charged with sulphate of copper and sulphate of zinc.—AUTHOR, Sept. 1854.

when that iron gains, or loses magnetic polarity. This application was first made by Mr. Wheatstone (as stated in the patent of January 1840). But although the possibility of employing the fluid, so obtained, for working needle instruments, was shown in the specification, it was rarely made use of, except for ringing alarms, to release the catches of which required a more powerful current, than that generally employed.¹ In 1851, Mr. Henley patented an instrument which is worked upon this principle.

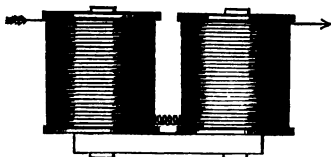
Fig. 8.



If a piece of soft iron A, (Fig. 8,) be placed opposite to the poles of a magnet B, it will itself become magnetic by induction, with contrary poles opposite to those of the magnet, and on withdrawing it from the magnet, the equilibrium of its particles will be restored, and all polarity in it will cease.

If a coil of insulated wire be placed round this piece of soft iron, the ends of this coil being connected (Fig. 9), and it be suddenly

Fig. 9.



presented to the poles of the magnet, as before mentioned, at the same moment that the iron assumes its induced magnetic polarity, a wave of electricity will pass through the wire coiled round it; the direction of the current varying as the polarity. Also, on quickly

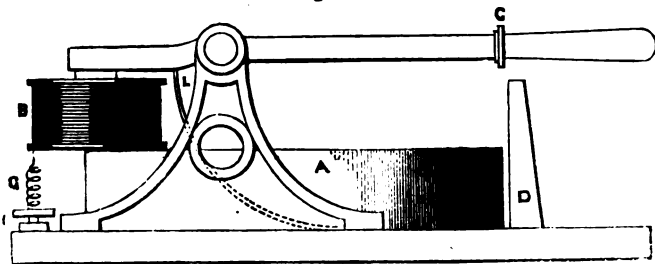
¹ The alarms rung by magneto-electricity have been very generally employed. Mr. Wheatstone's alphabetic dial telegraphs, worked by magneto-electricity, were established on the Paris and Versailles railway, and on other lines, in 1845, and acted very efficiently. In 1846 Mr. Wheatstone applied magneto-electricity to work the needle telegraph of the patent of May 1845. In this instrument one conducting wire only was employed, and the current acted upon two separate needles, deflecting one, or the other, according to its direction: the inverted currents were produced by means of two levers acting on the same armature of the magneto-electric machine. Mr. Henley, who had been employed in the construction of this instrument, subsequently, in 1851, obtained a patent for a modification, which consisted in producing the inverted currents, by the action of levers connected with two separate armatures.—

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withdrawing the iron from the magnet, another wave, more powerful than the last, will be evinced in the coiled wire, but in the opposite direction. The quantity and intensity of the current of electricity so produced, vary as the thickness and length of the wire coiled round the iron, or as it is usually termed, the armature.

Fig. 10 shows an elevation of Mr. Wheatstone's method of adapting this principle to ring bells for signals. A is the permanent

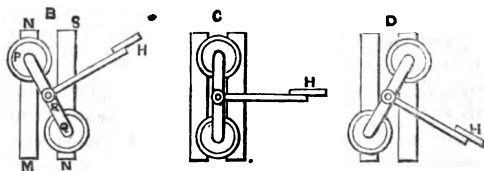
Fig. 10.



magnet, B, the soft iron armature, coiled with fine insulated wire, the ends of which G, and H, terminate in the binding screws I. C, is the lever by which the armature can be suddenly withdrawn from the magnet: D, an iron pin, which acts as a stop to the lever. L is a stout spring, connected with one of the ends of the coil, which presses, when the instrument is at rest, against the lever which is joined to the other end, and thus establishes a short circuit, to facilitate the working of the other instruments on the line, and thus obviate the necessity of sending the current through the long wire, coiled round the armatures of all the instruments.

Mr. Henley's invention, although based upon the same principle, is carried out in a somewhat different form. Fig. 11 is a representation of the arrangement he employs.

Fig. 11.



Two bar magnets, M and N, are placed parallel to each other, with their poles in opposite directions; and at either end of them is placed an armature, P, Q, coiled as above described, and which

can revolve on an axis *R*. *B*, *C*, and *D*, are end views of these magnets and armatures. It will be seen, that one end of the armature rests opposite to the North pole of one of the magnets, and the other end opposite to the South pole of the other magnet; which produces the same effect as if they were opposed to the North and South poles, respectively, of one and the same magnet. The action may be thus briefly described.

If from its quiescent position (as shown at *B*), the armature be suddenly shifted, by pressing the lever, or handle, *H*, to that shown at *C*, or perpendicular to the horizon, with the two ends between the magnets, the induced polarity in the armature will cease, and a current of electricity will pass through the wire coiled round it: and if the handle *H* be further depressed until the armature assume the position *D*, or with the same ends opposed to opposite poles of the magnets, a contrary polarity will be induced, and, therefore, another wave of electricity will pass through the coiled wire, in the same direction as the former; for it will be readily seen, that when magnetism ceases with one polarity and is again induced with the other, a similar current will result in both cases. On depressing rapidly, therefore, the handle *H*, so that the armature may pass from the position *B*, to the position *D*, a current of electricity composed of two distinct waves, but, from their rapid succession, acting in concert as one, will circulate through the coil of wire; and of course on returning the armature to its first position, which is accomplished with a spring, a similar compound wave will, from the same cause, be manifested in the opposite direction. Thus, then, a needle placed in a coil, as before described, the ends of which are connected with the wire coiled round these armatures, will be deflected in one direction, by depressing the handle *H*, and be deflected back in the other by releasing it.

There are two inconveniences attendant upon this sort of battery. First, if by any unforeseen circumstance, such as defective insulation, or other causes, additional power be required, it cannot be supplied, as with the ordinary battery, in which it is merely necessary to increase the number of cells. The second objection is, that it only deflects the needles in one direction, which therefore reduces a double-needle instrument, worked by its aid, to a value but little superior in point of signals, to a single needle, worked by the galvanic battery; this is however to be remedied, if found necessary, and even in its present form it is considered, by many, to be the best form of battery, yet used, for working the electric telegraph.

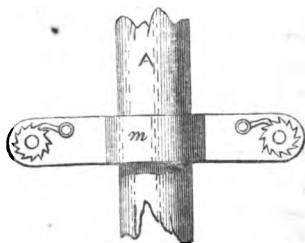
ON WIRES.

In considering the means of transmitting the magnetic power, it must be premised, that the method of insulation, now generally in use, is but a few steps removed from that adopted on the earliest lines of telegraph, laid down for public use.

Upon the Blackwall Railway the wires were insulated by cotton and shell-lac, and enclosed in an iron tube, placed a little above the surface of the road. The cost of this method was nearly £300 per mile, which was in itself sufficient to prevent the invention from ever becoming of any great use to the public. But judging from some experiments made upon his own grounds, and also upon the Great Western Railway, Mr. Cooke was led to believe, that a degree of insulation, equal if not superior to that obtained in this manner, might be acquired, by suspending the conducting wires upon high posts, placed at convenient distances from each other along the line: the insulation being further preserved, by interposing between these posts and the wires some non-conducting substance, such as earthenware, glass, &c. This, upon actual trial, between London and Slough, on the Great Western Railway, was proved to be correct; and the method has been, with a very few exceptions, generally adopted from that time until the present. The cost of this system is said to have amounted formerly to £150 per mile; but a double wire may now be laid down for £50 per mile, with a further sum of £10 per mile for each additional wire. The arrangement is simple, and to a certain extent effective. The following brief description will be sufficient to show the practical mode of carrying it out, at present, by the Electric Telegraph Company.

Strong posts, called stretching posts, of a suitable size, are fixed along the line, at distances of about 500 yards apart, and on each of these is secured a winding apparatus (Fig. 12) for tightening the

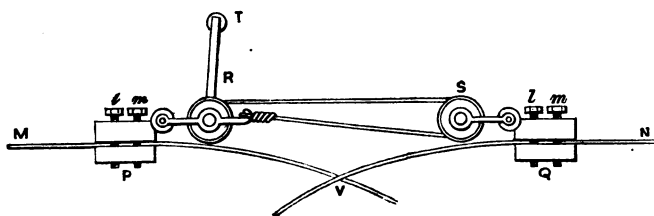
Fig. 12.



wires. Iron wires of No. 8 gauge, the diameter generally employed, are then suspended upon them, and are supported on intervening

posts, called standards, placed at distances averaging from 50 to 60 yards; the wires being insulated from each post, by passing them over, or through glass, porcelain, earthenware, or some such non-conducting substance attached to them. The wires are then drawn up to the required tautness and the operation is complete. The stretching tackle above described presents two material defects, viz. the great lateral strain upon the stretching posts, and considerable exposure to leakage, from the large metallic surface of the band *m*, connecting the winders in contact with the moisture with which the insulators are covered, in wet, or foggy weather. A stretcher invented by Mr. Poole, Fig. 13, remedies both these points, and is now, with some modifications of it, much in use. To the wires *M*, and *N*, which it is required to draw together, are fixed either tem-

Fig. 13.



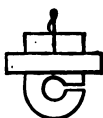
porarily, or permanently, two cast-iron clamps *P*, and *Q*, by means of a groove and the binding screws *l*, *m*: to these clamps is linked the draw tackle *R*, *S*, the lever *T*, serving to wind up the wires to the required degree of tautness. The wires may then be looped together at *v*, and the clamp be removed.

Many ingenious forms have been suggested for the insulating cups, through which the wires are made to pass, but all of them were open to serious objection, until Mr. Edwin Clark, in 1851, patented his metallic capped insulator, which has completely overcome all difficulties except those arising from fog.

From the fact of all bad conductors being good radiators, it may be noticed, that when the atmosphere is at all charged with moisture, porcelain, or glass insulators, from their radiating qualities, gradually cool down to below the dew point, and become covered with moisture: and thus while surrounding objects are comparatively dry, the very parts where moisture is most destructive, become effective condensers of that contained in the surrounding atmosphere. It struck Mr. Clark that this might be remedied, by surrounding this good radiator by some bad radiating substance, and one that absorbed heat with difficulty,—such as metal; and by way of experiment, a strip of copper one inch in width was suspended by a wire round one of

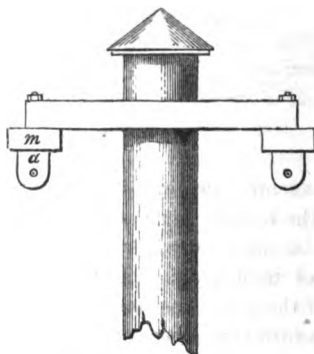
these insulators, about one inch distant from it (Fig. 14). It was then placed in the air, when dew was falling, and subsequently examined.

Fig. 14.



The porcelain cup, though elsewhere covered with moisture, exhibited a dry band, exactly corresponding in width with the strip of copper opposite to it, and even a small dry line was clearly traceable upon that part subtended by the wire which held it, thus clearly proving the correctness of the principle, and promising well for the success of the scheme; in practice it has been found, that all lines insulated on this system work freely in every weather, excepting always in fog, against which no known method of above-ground insulation avails. The ultimate form adopted for these caps is represented by the part (m), in Fig. 15, being constructed for the most part of zinc.

Fig. 15.



It was generally hoped, that the discovery of gutta percha would introduce a cheaper, and at the same time more efficient method of insulation; but it has been found, that economy is opposed to its general use, nor does it insure perfect insulation, unless double covered; as from the fibrous nature of the substance, minute pores will always exist, which admit moisture, and thus place the enclosed wire in connexion with the earth. This disadvantage is practically overcome, by enclosing the gutta-percha covered wire in a second coating of the same material, when unless imperfection occur in both at precisely the same spot, which is highly improbable, complete insulation is secured. The submarine cable laid down between Dover and Calais, is composed of four wires, each separately encased in two coatings of gutta percha, and bound together by a cord of hemp saturated with grease and tar, with the further protection of ten

galvanized iron wires, twisted round them, and intended as a safeguard against the friction of the shingle, &c. The cost of this wire was upwards of £350 per mile.

Another method of employing gutta percha, in aid of underground insulation, is to wrap a leaden case, by means of hydraulic pressure, round the single-coated wire, or wires. This plan, although serviceable for a short period, becomes useless at the end of a few months, from the extreme porosity of the metal; and the Electric Telegraph Company have been under the necessity of taking up all lines so laid down, and of replacing them with the old method of suspended wires. The price of the wires so encased for 1, 2, 4, and 6 wires in each, is about £30, £50, £100, and £150, respectively.

The system of insulation generally adopted for towns, and places where suspension of the wires is impossible, is to place a bundle of double gutta-percha covered copper wires in cast-iron pipes. The cost of this method varies with the number of wires required, but it averages generally about five shillings per running yard, or more than £400 per mile. The individual cost of each single-coated wire is about £16 per mile.

After Dr. Watson's first use of the earth current in 1748 the system was tried again in 1839, when the extra wire reserved for this purpose was dispensed with; and an instrument now requires only as many wires as there are needles.

Many experiments have been made relative to the conducting powers of wires, and the loss of quantity that an electrical current sustains, when sent through various distances: the two following, made by Professor Morse, have been selected as the most comprehensive and practical. In the first a length of 33 miles of insulated copper wire was employed. The quantity of the electricity was measured by the lifting power of a magnet excited by it, with a small steel-yard and weights, which though competent to measure the large quantities was quite unfitted for the smaller. The projection of the curve A, Fig. 16, shows the result, the horizontal dimensions showing the weight lifted, in ounces, and the perpendiculars the length of the wire in miles. Or,

With 2 miles the magnet lifted 9 ounces.

4	“	“	4	“
6	“	“	3	“
8	“	“	2½	“
10	“	“	2¼	“
12	“	“	1½	“
14	“	“	1¼	“

and every succeeding 2 miles up to 33 also ½ ounce. The great

difference observable between the 10th and 12th miles arising probably from the imperfection of the means of weighing.

Fig. 16. Curve A.

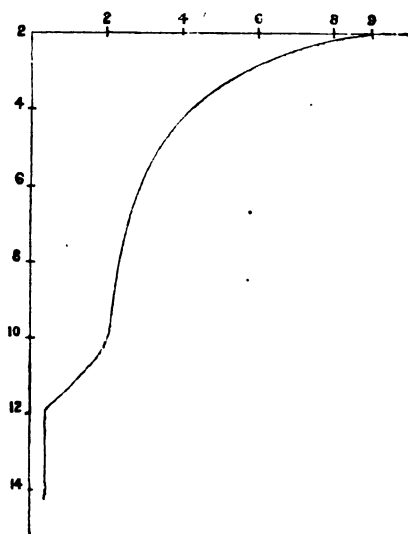
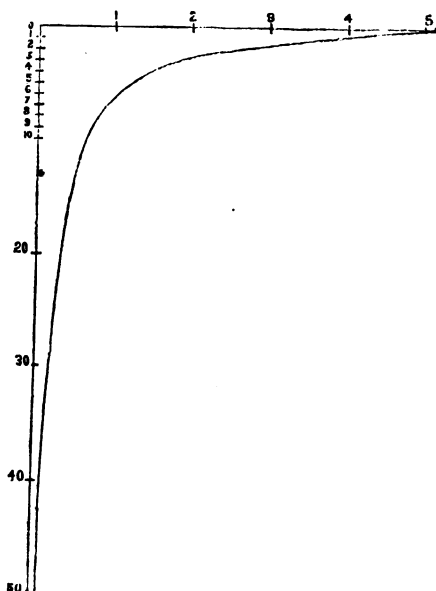


Fig. 16. Curve B.



In the next experiment a length of 160 miles of insulated copper wire, wound upon 80 reels, was employed, so that any length from 1 to 160 miles could be employed. Its power of decomposing water was tested, and the result is projected in the curve *B*, Fig. 16. Or the—

		Inches of gas.	
Battery alone decomposed 5·20 per minute.			
1 mile	„	3·85	„
2 „	„	2·62	„
3 „	„	1·84	„
4 „	„	1·20	„
5 „	„	1·05	„
6 „	„	0·92	„
7 „	„	·80	„
8 „	„	·71	„
9 „	„	·64	„
10 „	„	·57	„
20 „	„	·30	„
30 „	„	·20	„
40 „	„	·14	„
50 „	„	·094	„

According to Lenz, the quantities of electricity which can be sent through a series of wires, the lengths of which are in arithmetical progression, will themselves always be in geometrical progression.

Professor Draper, of New York, has made the following remarks upon this subject:—“ The curve whose ordinates and abscissas bear this relation to each other, is the logarithmic curve whose equation is $a^y = x$. 1°. If we suppose the base of the system which the curve under discussion represents, be greater than unity, the values of (*y*) between $x = 0$ and $x = 1$ must all be negative. 2°. By taking $y = 0$ we find the curve will intersect the axis of the *x*'s at a distance from the origin equal to unity. 3°. By making $x = 0$ we find *y* to be infinite and negative. Now assuming that the *x*'s represent the quantities of electricity, and the *y*'s the length of the wires, we perceive that those parts of the curve, which we have to consider, lie wholly in the fourth quadrant, when the abscissas are positive and the ordinates negative.

“ When, therefore, the battery current passes without the intervention of any obstructing power, its value is equal to unity, but as successive lengths of the wire are continually added, the quantities of electricity passing, undergo a diminution, at first rapid; and then more and more slow; and it is not until the wire becomes infinitely

long, that it ceases to conduct at all, for the ordinate $-y$, when $x = 0$ is an asymptote to the curve.

“In point of practice, therefore, when a certain limit is reached, the diminution of the intensity of the forces becomes very small, whilst the increase of the length of the wire is vastly great. It is possible, therefore, to conceive a wire to be a million times as long as another, and yet the two shall transmit quantities of electricity, not perceptibly different, when measured by a delicate galvanometer.

“Further, from this we gather, that for telegraphic despatches, when a certain distance is reached, the diminution of effect, for increased distance, becomes inappreciable.”

Professor Morse's experiments seem to show two things. First, the imperfection of the present method of insulation, a greater portion of the fluid being lost by leakage, than by the resistance of the conducting wires: and secondly, that it is possible to construct an electric telegraph between any two places, however great may be the distance between them.

ON INSTRUMENTS.

It remains now but to describe briefly some of the many instruments, or the distinctive parts of the principal instruments, which serve as a link in the chain of history of the electric telegraph, from its earliest days until the present time. It will be easily understood, that a reciprocal motion being given, such as the double deflection of a magnetic needle between two magnets, or conducting wires, or inside a coil of such conducting wire, and its fitness to produce a rotary, or other motion, either by escapement, or any known mechanical means being shown, the number of ways in which this power may be adapted, and thus various movements and effects produced, are innumerable, and it would be quite impossible in a paper of such prescribed limits as the present, to detail each scheme which has appeared; nor would it be profitable to do so, except in such cases as present either a new principle, or a more useful application of a known principle, than others which have preceded. Therefore when two, or more inventions have been made to effect the same object, the Author has preferred to describe but one, (not necessarily the best,) and merely to mention the others; since, however clever and ingenious they may be, neither time, or space can be allowed for a particular account of each individually.

Telegraph instruments may be divided into two distinct classes. First, those which send and exhibit transient, or passing symbols

requiring to be observed on the dial, and noted as sent; and, secondly, those which themselves permanently register the signals transmitted, and thus render the sender of intelligence independent of the receiver, who may decipher the despatches at his leisure.

The instrument produced by Mr. Alexander, of Edinburgh, was constructed with twenty-five needles, each placed in a separate coil in the manner already described: upon the axis of each was fixed a lever, (*m*) Fig. 17, carrying at its further extremity a paper screen (*n*); behind each of these screens was painted a letter of the alphabet, and the deflection of the needle, as represented at *D*, thus removed the screen, and disclosed the letter to be signalled. An extra wire was employed as the common return circuit, and contact was made with the battery, by pressing down keys, with the respective letters marked on them; thus, each letter had a key and a wire to itself. Immediately, however, after the exhibition of this instrument at a meeting of the Society of Arts, an anonymous correspondent of the "Mechanic's Magazine" proposed to have two letters painted behind each screen, and to show one, or the other at a time, by reversing the direction of the current for alternate letters, and so to deflect the screens in both directions, the angle of deflection being regulated by a stop. By this means thirteen wires would perform the same duty as was done by twenty-six with the other method. This was already an important step.

In June, 1837, Messrs. Wheatstone and Cooke took out their first patent, in which was detailed among others their five-needle instrument, the construction of which is as follows. 1, 2, 3, 4, and 5, (Fig. 18,) represent five indicators, upon the same axis with, and parallel to five magnetic needles, placed in coils of wire behind the face of the instrument, and capable of being deflected in either direction, by pressing upon keys situated in front of, and beneath the dial. 6, 7, 8, 9, are stops to regulate the angle of deflection. Lines are drawn from the axis of the needles to the stops, and produced both ways; forming ten lines intersecting one another in twenty-five points: at each of these points of section is written a letter of the alphabet, and consequently any two needles deflected simultaneously in opposite directions, will point immediately to the letter required. The needles

Fig. 17.

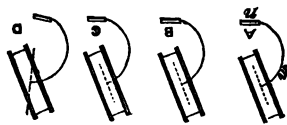
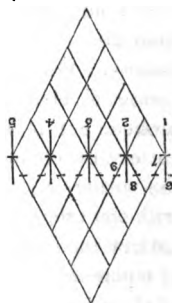


Fig. 18.

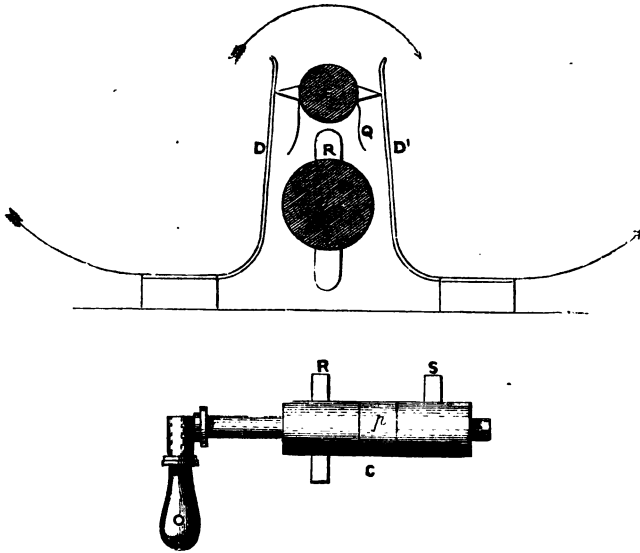


deflected singly denoted the numerals to which the lower end point. The constant changing of keys rendered the communication with this most beautiful instrument very slow, compared with those of more recent invention, and the fact of its requiring five wires was quite sufficient to insure its defeat by such as need but one, or two. It was used for some time upon the earlier lines, but was soon replaced by the double-needle instrument, also invented by Messrs. Wheatstone and Cooke, which, with their single-needle instrument, and innumerable variations of both, are still in use at the present time.

It will be remarked, that both the instruments, just noticed, indicate, by a single movement, the letter, or signal required, but it was soon discovered, that by the same sign being rapidly repeated once, or more times, (such combination of movements forming but one complete signal,) an equal number of signs could be transmitted with fewer needles, and henceforth no instruments were made with more than two; indeed many are employed with only one; but although these are equally comprehensive in their action, the working of them is slower on account of the number of repetitions which they unavoidably require.

In the instruments of Wheatstone and Cooke most generally in use, there are two needles, suspended in coils of insulated wire as already described, the ends of these coils being brought down and connected with binding screws, by which they are joined to the line wires which complete the circuit. To make a signal, it is necessary to break this circuit and to interpose the battery. For this purpose, one end of the coil, before it reaches the binding screw, is made to pass along a spring *d* (Fig. 19), across the bridge *e*, and down the spring *d'*, continuity of metallic contact being insured by the springs pressing against the bridge *e*. An arbor *c*, having two arms, *r* and *s*, vertically fixed upon it, runs underneath and parallel to the bridge *e*; this arbor is divided into two parts, insulated from each other by a piece of wood, or ivory (*p*); one end is placed in connection with the positive, the other with the negative pole of the battery. On revolving this arbor by means of the handle *o*, the spring *d'* being removed from the bridge, the original circuit is broken, but *d'* is placed in communication with one pole of the battery by contact with the lever *s*: also the lever *r* pressing upon the spring *q*, attached to the bridge, connects *d*, along the bridge, with the other pole, and thus the circuit is again complete, with the battery included in it, and a deflection of all the needles in the line of communication is the result. Of course if the handle *o* be moved in the opposite direction, contrary poles will be connected with the same wires, and so a contrary deflection will ensue. Each needle

has necessarily a separate break to itself, but only one battery is used, the current being divided, when both needles are employed
Fig. 19.

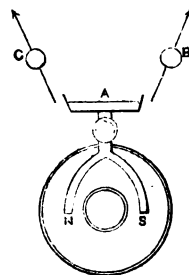


simultaneously. Each station is provided with a battery, which, by being thus inserted in the circuit, produces a signal in all the other instruments. It has been thought sufficient to explain the working of one sort of break only; but very many others have been invented, all equally effective; and it may easily be imagined, that an almost unlimited number of mechanical combinations might be contrived to answer the same end.

Very many modifications of the needle telegraph have been invented, and each method of moving a magnetic needle by the agency of the electricity has been patented several times, under various forms.

Messrs Brett and Little employ the form shown in Fig. 20; the coils being circular and the magnet, bent into the form *NS*, carries a lever *A*, which upon being deflected, moves the pointers *B* and *C*. Thus the evil arising from the oscillating motion of the needle is in part avoided, as the pointers are not in actual contact with it.

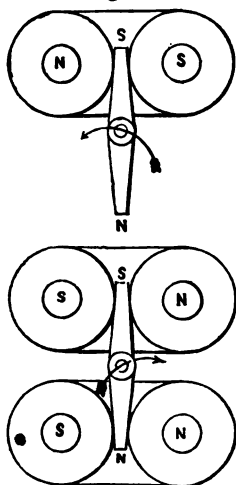
Fig. 20.



The needle is sometimes suspended with one or both poles between

those of an electro-magnet (Fig. 21). The pole of course deflecting towards that arm of the electro-magnet which has momentarily acquired a polarity contrary to its own.

Fig. 21.



The residuary magnetism retained by the electro-magnet, after contact with the battery has ceased, is however often sufficient, in these instruments, to hold the needle over, and thus to spoil the signals. With Mr. Henley's magneto-battery, as has been already shown, this is not the case, the wave of electricity, elicited as the armatures regain their first position, reversing the poles, and the needle is therefore deflected back with the same certainty and force that it is deflected forward. The inconvenience of residuary magnetism is also said to be practically overcome, by making the electro-magnet of a length not exceeding the diameter; and Mr. Dering has availed himself of this principle for the construction

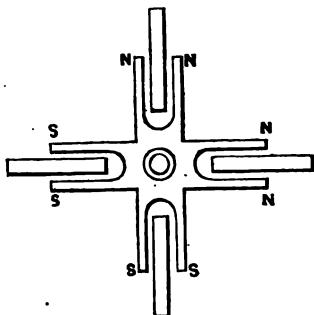
of a very simple instrument, something similar to that shown in Fig. 21, only, that the electro-magnet, instead of being in one continuous piece, is constructed of several discs of iron soldered together. Nickel is sometimes substituted for iron, in these magnets, because, although the magnetism induced in this metal is very slight, there is but little, or no residuary magnetism retained by it. A simple coil is also sometimes employed alone, without any metal at all; the attraction here is very slight, but still sufficient for telegraphic purposes.

Mr. Allan, with a view of gaining power, combines many magnets upon the same axis, by which he contends a great concentration of magnetic power is obtained. Fig. 22 represents one of the numerous combinations he employs.

In the needle telegraphs, the letters, or words are always signalled by concerted and arbitrary signs, and the code is composed of combinations of these signs and their relative succession. The next system of indicating telegraph is that in which the letter, or symbol to be transmitted, is itself pointed to by an index, or otherwise, actually and visibly shown upon the dial; as in the case of the five-needle telegraph already described. It was stated above, that an attempt was made early in the present century, by Mr. Ronalds, to construct a telegraph with dials, revolving by clockwork, but that

gentleman found an insurmountable difficulty in making the sending and receiving instruments, or as they are termed, the communicator

Fig. 22.



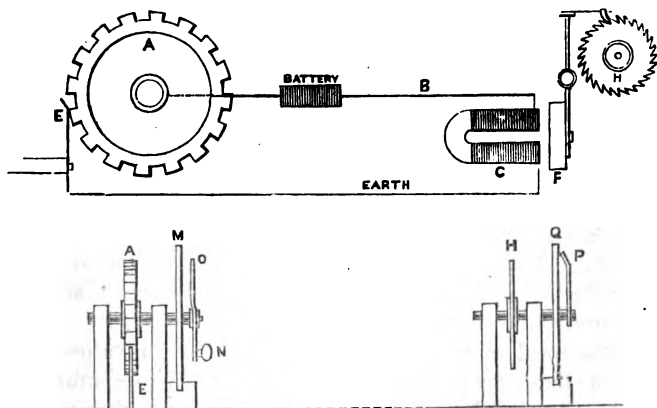
and indicator, revolve synchronously. It was first proposed by Messrs. Wheatstone and Cooke, in one of their patents, to rotate the dials step by step, by the aid of electricity, whereby all the instruments could be regulated by the same current, and similarity of motion would be insured.

The first telegraphs so constructed were used upon the Paris and Versailles Railway.

The manner in which an equal step by step rotary motion may be given to two, or more dials, or indices, by means of electricity will be easily understood by the following description.

A metal disc A (Figs. 23 and 24), is cut with as many teeth as

Figs. 23 and 24.



there are symbols required, (say 25 for the letters of the alphabet,) [1851-2.]

and connected with one pole of the battery, the other pole of which is connected with a wire, *B*, which passes round, at the place to be signalled, the electro-magnet *C*, and returning by the earth, the circuit is completed in the spring *E*, which presses against the toothed-wheel *A* in such a manner, that as each tooth passes by it, metallic contact is established, but that when a space between the teeth be opposite to it, there shall be no contact ; or the same end is better obtained by filling up the spaces between the teeth with dry wood, or ivory. Now, if the disc *A* be rotated by hand, the distance of one tooth, the electrical circuit will be closed and broken once along the wire *B*, to the earth, passing round the magnet *C*, which will attract the armature *F* ; and the wheel *H*, connected with this armature by an escapement movement, or any other mechanical contrivance, will also be moved through the distance of one cog. Thus, every time that a tooth of the wheel *A*, passes by the spring *E*, the wheel *H* will advance also to the extent of one cog ; and if the number of teeth in *A*, and *H*, be similar, when the wheel *A*, has gone once completely round, the wheel *H*, will also have made one complete revolution. Now, if a stationary dial *M*, upon which are painted as many symbols as there are teeth, be placed before the disc *A*, which can be rotated by means of a handle *N*, fixed upon the axis, the point *O*, of that handle, being opposite to one of the teeth ; then the cogged-wheel *H*, will be moved forward one cog each time that the index *O*, passes by one of the painted symbols on the dial *M*, and if *H*, carry upon its axle a needle, or index *P*, it will point out such symbol upon a stationary dial *Q*, placed behind it, provided similar symbols be painted on both dials.

The above description has been given, merely to show how the object might be accomplished ; but it will be directly perceived, that on this principle, there are innumerable ways of arriving at the same result, and many of which have been patented.

Among the most prominent modifications of this kind of instrument are the inventions of Messrs. Dujardin, Siemens, Brett, Poole, Highton, Nott, and Allan.

Some of the earlier rotary, step by step, indicating telegraphs, were set in motion by a weight, or spring, and a train of wheels, one tooth being allowed to escape at each motion of the armature ; but now the magnetic power is generally applied directly, and without the intervention of clockwork.

The reciprocal motion is often obtained, by causing a permanent magnet to vibrate between two electro-magnets, whose contrary poles are arranged opposite to each other : it being attracted to that with opposed, and repelled from that with similar polarity to its own ; in

this case, the current must not only be broken, but also be reversed for each letter; which is generally done, by employing two discs and springs, which connect the wires with the battery in different directions, and are brought into action alternately.

In the methods above-noticed, it will be observed, that a single failure of the electric current would suffice to destroy the correctness of the signals; for supposing that, from any cause, one letter were to slip, the communicator and indicator would then point to different letters, and the message would be no longer intelligible. Mr. Brett has remedied this, by causing both the communicator and indicator to return to zero, or the starting-point, after each signal, so that no fault can extend to more than one letter. Mr. Highton has also effected the same object, by causing the indicator, after it has signalled, the letter required, in the step by step movement, to complete the remainder of the circumference at one bound, by the action of the clock weight, or spring, without the aid of electricity, the indicator being thus brought again to the starting-point ready for the next signal.

Mr. Highton has also invented a telegraph, by which the symbols are instantaneously shown to the observer, without any step by step movement. It consists in the arrangement of screens perforated and inscribed with letters, fixed upon the axis of the needles, one before the others, in such a manner, that at each variation in the method of deflection, a fresh symbol is shown. The number of combinations thus attainable is three, (or the number of positions that the needle is capable of assuming,) raised to the power of the number of needles employed, less one, which must be reserved as a zero, or starting-point. Two wires will therefore only give $3 \times 3 - 1 = 8$ signals, and it will require 3 wires, or $3 \times 3 \times 3 - 1 = 26$ combinations to produce all the letters of the alphabet.

These form but a very small portion of all the indicating telegraphs which have been invented, but they will give a general idea of their principle, and of the chief features in their mode of construction.

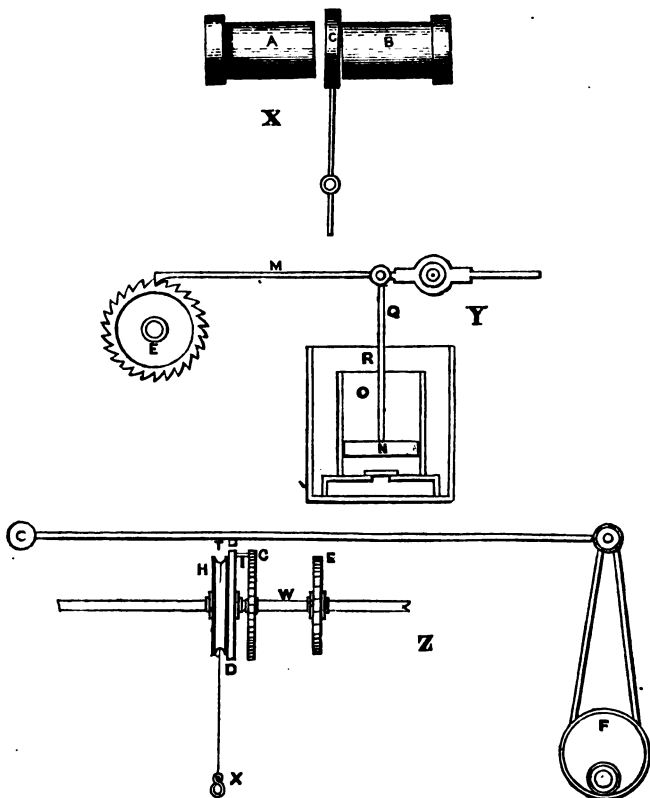
The last class of telegraphic instrument, which remains to be described, is that in which the signals sent are registered by the instrument itself, in a clear and indelible manner. This is performed by stamping, or printing, and by the decomposition of chemical mixtures by means of the electric fluid.

Of the first mentioned, the earliest instruments were those invented by Professor Morse, of New York, Messrs. Dujardin, Wheatstone, Steinheil, Bain, House, and Brett: and as the action of all depend upon nearly the same principles, it is considered sufficient only to

detail the last, which moreover possesses advantages not common to the others.

The reciprocal motion in Mr. Brett's instrument is obtained from the alternate attraction and repulsion of a permanent magnet *c*, (Figs. 25, 26, and 27,) by two electro-magnets, *A* and *B*, according

Figs. 25, 26, 27.



to the direction of the current. The end of the lever attached to it, releases by a peculiar escapement, at each movement of the armature, one tooth in a train of wheels *E*, having as many teeth as there are letters cut upon the wheel *D*, on the same axis, and one opposite to each; so that the required letter upon the wheel *D*, can be brought uppermost, by reversing the current a certain number of times. The lever *M*, working into the teeth of the wheel *E*, moves also a second escapement, independent of the last, which releases an

eccentric, *f*, moved round by clockwork, about one-tenth of a revolution of the eccentric being accomplished with the up-stroke of the lever *m*, and the remainder with the down-stroke: by means of this eccentric, the lever *τ*, is pressed upon the type wheel, and prints the uppermost letter upon a piece of paper placed between them. But it will be observed, that in this manner, each letter as it passed would be printed, and consequently no two letters, out of the order in which they were arranged upon the type wheel, could be indicated, without printing the intervening letters also, which would of course render any communication quite unintelligible: to avoid this, Mr. Brett has invented what he calls his "water regulator," represented in *Y*, by which the action of the piston is rendered much more tardy in the down-stroke than in the up-stroke; thus, though the wheel *ε*, be made to revolve ever so much, no down-stroke will be made by the lever *m*, until some short pause, which may be a fractional part of a second, when it will descend from its own gravity, and the eccentric *f*, being released, the letter required will be printed.

Another of Mr. Brett's improvements, consists in causing the type wheel to return, to zero, or the starting point, after each signal, so that if an error be made, it will be immediately corrected in the next letter. The type wheel *d*, is not permanently fixed upon the same axle with the wheel *ε*, but together with the wheel *h*, which is of a piece with it, is merely placed loose upon the axle, and caught to the permanently fixed wheel *c*, by the pin *i*. As the wheels *ε*, and *c*, revolve, by means of the escapement and weights, the wheels *d*, and *h*, are carried with them, the latter winding up the small weight *x*. The same movement however, which stamps the type upon the paper, by an arrangement which it is unnecessary to detail, releases the pin *i*, from the wheel *c*, and the wheels *d*, and *h*, are directly carried back by the weight *x*. This instrument has, for the convenience of description, been drawn in different parts, and with a somewhat varied arrangement; but it is believed that the principle is correctly shown. The details of the various parts are deserving of very particular observation, and the Author would recommend it to the attention of such as are not yet acquainted with this ingenious piece of mechanism.

For the aid of printing, and all instruments which require more force than is obtainable from the feeble current which can be sent along great distances, Messrs. Wheatstone and Cooke have introduced in their patents a means of calling into use a secondary, or local battery, by which a current may be sent in the direction and of the force required. They term it, a "pecker," or, relay circuit.

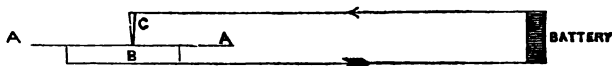
Mr. Highton has patented an instrument for the same object, which he calls, a "perænode."

Mr. Highton has also invented a telegraph which, by the combined action of three perænodes, prints directly, and without the aid of any step by step movement, all the letters of the alphabet. The principle is the same as that of the indicating telegraph with shields, being based upon the possible number of combinations of the polarities of 3 magnets taken 1, 2, and 3 together. But this kind of telegraph would of course require 3 wires.

In all the telegraphs hitherto described, whether indicating, or printing, the prime agent is electro-magnetism, in one of the many forms it is capable of assuming; there is, however, another class in which this power is entirely dispensed with, and which rely solely for their effect upon chemical decomposition.

The tendency of electricity to produce chemical decomposition, is well known, and need not be referred to, except in its application to telegraphic uses. If B, (Fig. 28) be a piece of metal placed in com-

Fig. 28.

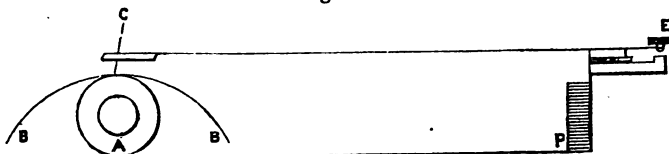


munication with the negative pole of a battery, and A, a piece of paper moistened with a solution of acid, (such as muriatic acid) and water, laid upon that piece of metal; and c, be a point of some metal, (such as iron,) in connection with the positive pole of the battery; when this point is laid upon the paper, the acid contained in the latter will be immediately decomposed, and combining with the iron will form a muriate of iron; and if the point be drawn across the paper, or figures traced with it, there will remain lines, or figures of muriate of iron upon the surface of the paper, wherever the electrical current was allowed to pass: this muriate of iron is invisible, but if the paper be washed with one of the many known tests for iron, such as prussiate of potash, the lines will be clearly brought out, as if they were written with common ink; or the same effect is produced, if the prussiate of potash be mixed at first with the acid, before moistening the paper, in which case the lines will be immediately visible so soon as the chemical decomposition takes place; and this is the method generally adopted.

The following is Mr. Bain's application of this principle for telegraphic signals. A, (Fig. 29,) is a metal roller connected with the negative pole of the battery P, and c, is a steel point, connected with the positive pole; B, a strip of chemically-prepared paper capable of

passing between the two, but touching both. The battery of course is at the other end of the line, and connected with the roller and

Fig. 29.



point by wires, or one wire, and the earth. The poles of the battery are joined by pressing the button *E*, and the circuit broken by releasing it. Consequently, each time that *E*, is pressed down, a mark is made upon the paper at *C*, and if the paper be drawn along over the roller, a line will be marked, so long as the current continues to pass, but the paper will remain white when the current ceases. It is easy to conceive, that an alphabet of long, or short lines, and dots combined together may be made, to render these marks intelligible such as are shown in Fig. 30, which is part of the alphabet actually

Fig. 30.

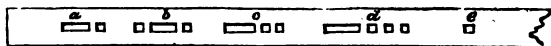


in use; and it is difficult to conceive a simpler telegraph, or one less liable to get out of order.

In actual practice the paper is moved by clock-work, and the key, or break is something different from that shown in the drawing, for the greater facility of connection with batteries and line wires. The decomposition too is generally effected by a local battery, which is set on by a pecker, as described above.

The method adopted, in the first instance, to produce these lines and dots, was to previously punch, with a machine invented for that purpose, similar symbols in a piece of paper, (Fig. 31,) and this was

Fig. 31.



drawn along between a spring connected with one of the line wires, and a roller in communication with the other, the battery being included in the circuit. Thus, as each open space passed, the spring pressed upon the roller, and connection with the poles of the battery was established, and when the other portions of the paper, where no hole existed, passed under the spring, the current was cut off. But it was soon discovered, that sufficient uniformity of movement could

be given by the simple key, above described, to render the communication perfectly intelligible.

An ingenious application of the above arrangement has been patented by Mr. Bakewell, for the purpose of copying writing. The characters are inscribed in some resinous, or other non-conducting material upon metal. This metal, which may be tin-foil, is then placed round a roller, and connected with one pole of a battery; while a metal point communicating with the other pole is placed in contact with it; the roller is then made to revolve, and it will be seen, that these poles will be connected, while the point passes over such parts as have no writing on them, and that the circuit will be broken, as the point passes over the non-conducting writing. If then these wires be continued to the station to be signalled, and a point in connection with the positive pole, be made to pass over prepared paper laid upon a similar metal roller in connection with the negative pole, which must revolve equally and simultaneously with the other, then a line will be produced as *A B* (Fig. 32,) but broken at such places as the line crosses the written characters; and if many such lines be drawn, parallel and near to each other, a facsimile of the written characters will be obtained, white upon a coloured ground.

Fig. 32.



It would not be out of place here to give a description of some of the many bells and alarms, invented to work in connection with the electric telegraph; but as their action is purely mechanical, and electricity being merely employed to disengage a stop, or catch, which releases a train of wheels moved by a spring, or weight, the Author has preferred confining himself to the actual subject of the paper.



Such then is a brief description of the principal features of the electric telegraph, as it exists at the present time. There is possibly no invention that has tended so much to the furtherance of commercial intercourse, and consequently to the civilization of man, as the electric telegraph. It is indeed doubtful, whether the railroad would ever have attained its present perfection, without the aid of the telegraph, and now by their combined influence, it becomes possible almost to annihilate space, and practically to abolish time.

It must not however be supposed, that there remains nothing more to be done, in respect to this invention, and that the various systems pursued at this moment are incapable of improvement, for as the present appears perfection to the past, so surely will a future arrive, when the imperfections of the present will be perceived.

The Author has endeavoured to point out the several parts of the electric telegraph, which are less perfect than the rest, and which afford the greatest scope for improvement, namely, the battery, or other motive power, and the means of insulation, the present above-ground insulation being uncertain, and the under-ground too expensive: and he would suggest to such members as are practically, or professionally connected with this branch of study, the necessity of turning their attention to the improvement of these points, which stand most in need of reform, rather than to the invention of new instruments, in which division, probably, perfection can be carried little further, until some important change be effected in the other departments.

The paper is illustrated by a series of diagrams, from which the woodcuts are compiled.

Mr. WINDOW explained, that his object had been to produce a general account of the Electric Telegraph, rather than to give a detailed description of the inventions, or of modifications of the various systems, which were so numerous, that he had found great difficulty in even barely alluding to the instruments, within the limits of a Paper, to be read at a meeting of the Institution. He was glad to find, that Mr. ADLEY had entered more fully into the subject, and he congratulated the members on the possession of so useful a Paper.

He then proceeded to explain the action of the double-needle instrument, of Wheatstone and Cooke, in which the letters were signalled by a combination of the movements, or deflections of the two needles, each word being acknowledged from the other end of the line, before proceeding with the next. He then, after a few observations upon magnets, illustrated by Wheatstone's bell-ringing instrument, explained the working of Henley's magneto-telegraph, showing that much additional sensitiveness was gained by the needle being deflected both backwards and forwards, instead of being returned by a spring, or weight, as in the case of the double-needle instrument. He then explained, in detail, the working of Brett's printing,—Bain's decomposing "dot and line,"—Bakewell's copying,—and Siemens' indicating and printing telegraphs.

Mr. ADLEY explained, that in attempting to write a Paper for the Institution, he had sought in vain for some practical treatise, from whence he might learn the details of many proceedings that had not come under his own observation; he had thus been induced

to extend his Paper, hoping that it might aid some future labourer in the same field.

Mr. C. W. SIEMENS said, that the arrangements of the instruments and wires which had been adopted and executed by his brother, to a large extent, in Germany and in other countries, differed essentially from other systems.

The instruments he used (and which were exhibited on the table) were both of the pointing, and the printing classes. The former consisted in the outward arrangement of a dial, around which were placed thirty radial keys, each of which bore a letter of the alphabet, or other sign (the letters which most frequently occurred being repeated at opposite points). A hand on the dial revolved continually, when the circuit with the battery was completed, but was stopped opposite any key, which was depressed by the operator. A similar instrument was placed at every station, the hands of which were compelled to rotate and to stop in concert, by depression of a key at either station.

When the telegraph was not used, the batteries at all the stations were disconnected from the instruments.

The first step then, in sending a message, was to move a small handle, (whereby the battery of the station was put into circuit), the effect of which was to ring a bell at the nearest station. On hearing the alarm, the officer at that station also moved the handle of the instrument before him, and the dial hands of both rotated simultaneously. The message was thereupon transmitted by simply spelling the words by the depression of the keys, on the one side, and by reading the letters, indicated by momentary stoppages of the pointer, on the other. If the officer at the second station received only a sign denoting a succeeding station, he had to move the handle into a third position, whereby he excluded the instrument at his station, and gave the alarm at the following and so on.

Another position was, that all the instruments along the line were in circuit, and received the message simultaneously.

This instrument was well adapted for railway service, and for intermediate correspondence generally, because it could be worked at first sight by any uninitiated person. It afforded peculiar facilities for communicating either to one, or many stations collectively, and it permitted the ringing of bells, and other signals, through one and the same wire, without causing confusion in the transmission of messages.

He might mention, as an instance, the line from Berlin to Hamburg, where one main wire served for the transmission of messages, and for announcing the progress of every train from station to station,

by the ringing of large bells, which were stationed at every crossing, and at such distances apart, that the one, or other could be heard at every point of the line. By this arrangement collisions of trains were rendered almost impossible.

Another instance, worth notice, was the town telegraph of Berlin, which combined all the police and fire stations in such manner, that the alarm of fire was spread in an instant through the district; so that the director might communicate from the central office, at his pleasure, either to one station only, or to a whole group collectively; all this was accomplished by one circular line of wire.

The printing instrument (or secretary) might, or might not be joined to the pointer instrument, just described. Its function was to print the messages given and received, in common type upon strips of paper; thus giving a duplicate record of the communications, at both ends of the line, and avoiding all possibility of error.

It would at first sight appear doubtful, whether it would be practically possible to ensure the simultaneous movement of the rotating hands, or pointers, besides working alarms and printing mechanism, all by the same wire and battery. These doubts must, however, disappear, on inquiring into the peculiar principle of action, which had been adopted. Unlike other telegraphs, where the communicating instrument was worked by hand, or clockwork, or where the receiving instrument was assisted by such, the instruments in question were purely electrical machines, in which reciprocating motion was produced by the independent action of the instrument, in alternately breaking and restoring the galvanic circuit. Between the poles of a horse-shoe electro-magnet, an armature was placed transversely, upon a spindle parallel to the shanks of the magnet, so that the attraction of the armature, by the electro-magnet, produced an angular motion of the former. A spring was attached to the armature, which caused it to fall into its distant position, whenever the magnetism ceased, by the break of the circuit. The armature carried with it a lever, to the end of which a ratchet was attached, which moved a ratchet wheel through the breadth of one tooth for every oscillation of the armature. The spindle of this ratchet wheel carried the hand, or pointer on the dial face, and the number of its teeth corresponded with the number of keys around the dial. The working lever carried, also, two insulated projections, with which it struck, towards the end of each stroke, against projecting lugs of a lever below, which, by the slight motion imparted to it, alternately broke and restored the circuit, exactly as the valve lever of a steam-engine alternately admitted and discharged the steam. The circuit of the line wire was not completed, until both,

or all the communicating instruments had accomplished their return stroke, and until then, no fresh motion could take place.

In depressing a key of any one instrument, a projecting lever on the ratchet wheel was stopped opposite the same, the oscillating lever was thereby arrested about half way in its return stroke, and was, consequently, prevented from re-establishing the circuit. The pointers on all the instruments stopped at that moment opposite the same letter of the alphabet, and could only resume their motion after the depressed key was released. The internal arrangement of the printing instrument was the same as that of the indicating instruments, with this exception, that instead of the pointer upon the rotating spindle, there was a disc of thin steel plate, divided into thirty segments, upon the extremities of which, types representing the letters of the alphabet were soldered.

The instrument contained a second electro-magnet, of comparatively large dimensions, through the coils of which a local battery current passed, each time the working lever of the instrument made an oscillation ; but it had no effect, because the duration of each successive current was insufficient to effect its massive armature. On stopping the instrument, (by the depression of a key), the local current of the large magnet continued and caused it to attract its armature. This caused a hammer to strike with considerable force, under a letter of the type wheel, corresponding with the letter on the depressed key, which was forced upwards against an inked cylinder, and impressed distinctly upon an intervening strip of paper. The motion of the hammer instantly broke the local circuit, and in falling back it moved the inked cylinder and paper through the breadth of one letter by a ratchet motion, thereby fitting it for the reception of another impression.

The alarms were worked on a similar principle.

It had been a matter of surprise, how it was possible to produce such powerful effects by the galvanic action, without the aid of clockwork, &c., seeing that under ordinary circumstances it hardly sufficed to release a detent, or to deflect a needle. The advantage of the principle of self-interception of current was here made apparent. It enabled them to include the batteries at the various stations into the circuit, so that each battery had only the resistance of a section of the line wire to contend with. Moreover, a small portion, only, of the active current required, to pass the wire at all, the greater portion being what was commonly called "bad circuit" or "derived current" (and which was produced artificially).

An important feature in his brother's system, was the use of gutta percha, for coating the under-ground line wire, which was first

suggested by him in the year 1846, and had since been carried out to the extent of upwards of four thousand English miles.

The advantages of the under-ground system were,—that it was not affected by atmospheric influence, such as fog, lightning, aurora borealis, or sudden changes of temperature, which frequently broke the suspended wire; it was also expected to be more durable, when properly protected, and lastly, it was beyond the reach of mischievous, or riotous persons. The gutta percha coating was attacked by two enemies, the atmospheric air,—which gradually converted it, by a process of oxidation, into a hard and brittle mass, through the crevices of which the moisture gained access to the wire,—and a species of field rats, which gnawed the wire where it obstructed their mining operations. These two causes, combined, had destroyed the insulation of several of the early lines, particularly in dry sandy embankments. It was therefore found necessary to protect the gutta percha, by an external coating of lead, which was drawn tight over it through a die. The earlier lines were, moreover, laid only 18 inches below the surface of the ground; but it was found necessary to lay them from 2 feet to 2½ feet deep. The weight and cost of the under-ground line wire, per English mile, was :—

	£.	s.
Copper wire, 80 lbs. at 1s. . . .	4	0
Gutta percha, 68 lbs. at 3s. . . .	10	4
Lead, 600 lbs. at 3d.	7	10
Total . . .	£21	14

exclusive of workmanship and delivery. The cost of the trench work differed, of course, with the depth and nature of the soil; the following might, however, be taken as the average cost per mile of a single-wire under-ground telegraph :—

	£.	s.
The gutta percha and lead coated wire	21	14
The trench 2 feet deep, including filling up again	6	0
The instruments and sundries	8	6
Total . . .	£36	0

or about £30 when the lead coating was dispensed with and the gutta percha was increased to about 100 lbs. per mile.

In Germany the trench work was generally taken by contract, at 2½ or 3 silver groshen per 12 feet, which was somewhat less than £6 per mile. Recourse had, in some cases, been had to a species of

plough, which was propelled at a walking pace along the line, by a locomotive engine, and whereby the cost of ground-work was much reduced.

It appeared at first to be a serious difficulty, to discover the places of rupture, or of bad insulation, in the under-ground line wire; this had, however, been successfully removed by a simple system. To discover a place of rupture between two stations, a battery was inserted at one station, between the line wire and the earth; an officer then proceeded about midway between the stations and connected a galvanometer with the earth on one hand, and the line wire (which was at intervals accessible by being brought up into testing posts) on the other. If he observed a deflection of the galvanometer needle, the rupture could not be between him and the station with the battery. He therefore proceeded to the next post, in the direction of the other station, and so on until he found, upon repeatedly attaching the galvanometer that no deflection took place. The rupture must therefore be situated within the distance, between two testing posts, which distance was thereupon halved and quartered by digging holes, and thus obtaining access to the wire. In the course of an hour the position of the rupture was generally ascertained, to within a few yards, which were taken up and a fresh piece of wire soldered to the main wire in two places.

The position of a place of bad insulation was discovered by an application of Ohm's law, without proceeding along the line wire. A delicate galvanometer was placed with its battery at the end station, in succession, and the degree of deflection observed. The amount of deflection was inversely as the resistance and the latter was composed of the resistance of the line wire to the place of leakage, the resistance in the imperfect medium of insulation through which the current escaped into the earth, and finally in the resistance of the earth and battery. The two latter resistances would, in both cases, be the same, and the difference of deflection was, therefore, solely owing to a difference of resistance in the two sections of line wire, which by Ohm's law gave a measure of their respective length.

Professor AIRY had listened with great interest to the Papers, and the explanations of the preceding speakers. The subject of electric telegraphs, generally, was so wide, that he would not venture upon it, but would confine his observations to a very few points of importance, in his view, but which were not so likely to attract the attention of Civil Engineers.

The term "electric telegraph" was, in his opinion, objectionable;

it should be "galvanic" or "voltaic." It was to be regretted, that Dr. Faraday, whose valuable researches had done so much for that, as well as almost all other branches of science, should have employed the term, as it had created confusion, which it would have been desirable to avoid. Galvanism had a close connection with magnetism, and it bore some remote relation to electricity; but he must contend, that it was not correct to use the term "electricity," in designating galvanism. It might be affirmed, that during the greatest atmospheric disturbance from active electricity, there was very little display of galvanism. That there was some remote connection between them could not be doubted, but at present, with so little in common between them, it must be regretted that, even in familiar phrase, the terms should be confounded, or misapplied.

In this, as in many other instances, art was the leader of science, and it had been shown to be the case here, by the assistance which the telegraph wire had given, in tracing the courses of those galvanic currents along the surface of the earth, which possibly were the cause of those strange derangements of the magnets, formerly so little known, but now occurring so frequently, and to which, as a matter of physical science, the greatest importance must be attached. The nature of those magnetic storms, or by whatever name they were known, was at present but little understood, indeed the entire subject of terrestrial magnetism was still plunged in great obscurity. It was an important question, to determine the causes of those abnormal disturbances, and anything that could elucidate the subject was of importance. Taking the general facts, and especially those which had been brought together by Mr. Barlow, it did appear, that the indications of the galvanometer of the telegraph, exhibiting the currents, which passed from it under the earth, were calculated to assist in the consideration of the question, and it was worth while to direct the attention of Engineers to the point, whether it was possible to construct any self-registering apparatus for these observations; nothing very definite had hitherto been promulgated, as to the disturbances of the telegraph needle, and if the photo-self-registering process was used at all the stations, curious results might be obtained. In some cases, it would be well worth the expense of laying down a single line of wire for the purpose of experiment; as for instance, a line from London to Brighton, which was a straight line, in one direction, and another from London to Ipswich. He ventured to throw out those hints, suggested to him by the connection which the science he more particularly professed had with the practical subject of art before the meeting.

At the present time a telegraphic communication was nearly completed, between the Greenwich Observatory and the South Eastern Railway Station; and here he must embrace the opportunity of bearing testimony to the ready attention given to the subject, by the Government, and the facilities granted by the Electric Telegraph and the South Eastern Railway Companies, by whom the design had been received most willingly, and who had given their cordial co-operation. The scientific object in view, was an instantaneous connection between the British observatories and those of the continent, through the agency of the sub-marine telegraph. By this widely-spread connection, one of the objects to be arrived at would be a determination of the difference of longitude; and a scarcely less important one was the connection of all the clocks, in the various quarters of England, where telegraph lines extended; so that Greenwich time could be known simultaneously in all parts of the kingdom, with an error not exceeding one-tenth of a second. This was not intended to pre-judge the question, whether Greenwich time ought to be employed, or not; but it must be an advantage to have the power of ascertaining it correctly. It might, perhaps, be interesting to the meeting to know what was being done, in the first introduction of this system; he would briefly explain, that the Electric Telegraph Company was introducing a novel and beautiful system for distributing and establishing correct Greenwich, or uniform time throughout the country. For this purpose telegraphic wires were being laid down over the North Kent Railway and through Greenwich Park to the Observatory, and by the permission of the South Eastern Railway Company, the wires were carried from thence to the Telegraph Office in the Strand, on the dome of which there would be fixed an elevated pole, similar to that on the top of the Observatory at Greenwich, and from which, every day at noon, a large black ball, 4 feet 6 inches in diameter, would be dropped, through the agency of galvanomotive power, and falling on a proper contrivance at the base of the pole, would communicate standard time, through the existing wires diverging from and to Lothbury and the Strand, by an electrical action throughout the country. There would also be established, in connection with this great movement, first-class "regulators" at all the principal commercial towns, which would be daily set to Greenwich time, by preconcerted signal, from the Strand, over all the telegraphs in England, Scotland, and Wales. It was also in contemplation to regulate the clocks at the Royal Exchange, the new Palace at Westminster, the Horse Guards, and other public establishments, on the same principle. The Electric Telegraph Company also intended to place opposite some of their metropolitan

stations, in the streets, ornamental lamps of a novel construction, with a clock and an illuminated dial plate on the four sides of the lamp, which would indicate to the public, by day and night, exact Greenwich and railway time. These were manifest public improvements, and for which the public, as well as scientific men, were indebted to Civil Engineers.

Mr. EDWIN CLARK was aware of the numerous modifications of the instruments described in the paper, and had carefully examined them, with a view to employing any that really offered increased facilities, combined with certainty of action; the difficulties of insuring correct delivery of messages, did not, however, depend so much on the instruments as upon other points;—for instance,—the perfect insulation of the wires was indispensable, yet the most (apparently) insignificant causes sufficed to injure the insulation; and although, theoretically, there did not appear to be any limit to the conveyance of magnetic fluid, yet, practically, the difficulties were immense and demanded all the resources of ingenuity to meet them. The stoppages complained of, more frequently resulted from wilful damage, than from accident; but from either cause they were, now, very rare.

In answer to the often repeated question, whether the over-ground, or the under-ground system of wires was to be preferred, he would say, that the difficulties in going through the air, though great, were not more serious than those encountered in the under-ground system. The system hitherto generally employed by the Electric Telegraph Company, was that of suspending the galvanized iron wires stretched between poles, at a certain height from the ground; this was by no means intended as a temporary system, as it was found to be cheap in construction, simple in working and efficient in the results. In a humid climate, like England, there was, however, to be combated, the effect of condensation upon the wires, and of deposition of carbon from the coal smoke upon the insulators, in certain districts, by which perfect insulation was rendered extremely difficult, and under peculiar circumstances the under-ground system had been tried with such an amount of success as to induce further trials, as it appeared possible to meet the objections hitherto raised to it; there were localities in which it might be advantageously employed, and he did not despair of using it, where the application of the suspended system was attended with difficulties.

In London and other town communications, the Electric Telegraph Company had three hundred miles of under-ground wires. If any damage arose to the wires above ground, it was, by inspection, soon

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seen and easily corrected, but when a fault occurred under-ground, although the spot was known, within a short distance, a certain length of pavement had to be raised, before the defective point was reached. The wires could not be covered with gutta percha under £15 per mile, whilst ordinary galvanised iron-wire cost £7 per mile. The poles in general use would last perhaps ten, or fifteen years, and with their four thousand five hundred miles of line, the falling of a pole was a rare occurrence, and by way of rendering them more secure, Mitchell's screw pile-shoes had, latterly, been extensively employed for posts and braces. They had used a great deal of lead covering for the wires, but it was now all removed, being found defective. They now enclosed the under-ground wires in cast-iron pipes, and took every precaution for preventing any contact with gas, or water-pipes.

Mr. ADLEY, in answer to questions from the President, said that atmospheric influences were severely felt under all the telegraph systems, and there were many phenomena yet completely unaccounted for. There was more electricity in the air in winter, than in summer, yet there was less at night than during the day. Wells, in his "Treatise on Dew," appeared to controvert the opinion of there being any connection between the formation of dew and the electrical state of the atmosphere.

The principal difference between the American instruments, introduced by House and by Morse, was that the former required an attendant to be always present, whereas the latter did not.

Mr. J. W. BRETT, referring to the Submarine Telegraph, stated that the credit of the first suggestion was due to his brother and himself conjointly; that in 1845 they declared the feasibility of the plan, if the insulation of the wire, by means of caoutchouc, or other vegetable gums, could be rendered permanent. The first attempt, to lay a wire covered with gutta percha between the coasts of England and France, was considered merely as an experiment, and could not have been expected to be permanent. The submarine cables, as now constructed, might be considered capable of enduring half a century, unless they were subjected to such extreme tension as would produce disruption. From investigations he had made, he was inclined to think, that eventually the system of under-ground communications would be preferred; all the defects were remediable; but with it, as with all new systems, time and perseverance were requisite. He had found this, in establishing the submarine communication, and, even to the present time, he had only been able to work partially with his printing telegraph, as he had not been able to devote the necessary time to certain alterations, demonstrated by

practice to be necessary, and therefore the double-needle instrument had hitherto been generally used in connection with it. The printing telegraph was in extensive use in the United States, for commercial purposes, and the clerks at the telegraph offices became the legal attesting witnesses to all transactions so concluded.

Mr. WHISHAW wished to direct attention more particularly to the under-ground system of communication. Some years since he had reported for the Honourable East India Company on the subject, and then advocated that plan, as being best calculated for the climate of India; and Dr. O'Shaughnessy who, as early as in 1839,¹ had published most interesting experiments on electric communication, had corroborated his opinion. The experiments alluded to were made in the Botanical Gardens at Calcutta by suspending a length of twenty-two miles of wires, on bamboo posts, so placed that any separate portion could be experimented on; and in consequence of observations at that time, Dr. O'Shaughnessy made a long report to the Honourable East India Company, giving an opinion adverse to the over-ground system, upon the assumption that if in temperate climates, the atmospheric influence was so injurious to the needle telegraph, it would be much more so in the climate of India. He laid down a telegraph wire under-ground, from Calcutta to Diamond Harbour, a distance of twenty-two miles, but could not state positively whether it would eventually be successful, because he had not the means of effectually insulating the wires.

Being so fully impressed with the advantages of the under-ground system, Mr. Whishaw had visited Prussia, where it was chiefly employed, and from his personal observations, he could confirm all Dr. O'Shaughnessy's statements; and he was convinced, that when the gutta percha was enveloped with a coating of lead, it would form a conducting medium far superior to that of the over-ground system.

During an engagement under the Electric Telegraph Company, he had ample experience in the over-ground system in England; the numerous casualties arising from atmospheric influence, trains running off the rails, snow, wanton, or malicious mischief, and many other causes, induced him to turn his attention to the under-ground system, and he projected several modes of carrying wires beneath the surface. One was by means of the multitubular pipe, separating the wires; another mode was to use the ordinary drain-pipes, and to carry the wires through plugs of gutta percha, effecting the same object at a small cost. Drain pipes could be laid down for £3, or £4 per

¹ Vide "Journal of the Asiatic Society of Bengal," Calcutta, September, 1839.

mile, and wires so put down would be sufficiently insulated. Still he should prefer the plan, adopted in Prussia, of first coating the wire with gutta percha, then coating it in lead and laying it at a sufficient depth below the surface.

There should be, along the whole line, testing posts, like those used in the streets by the Electric Telegraph Company; any injury could then be ascertained, within a quarter of a mile, and the defect could be easily remedied. The neglect of this precautionary measure had caused much trouble and was one of the reasons why the Company did not at first establish the under-ground system. If the use of gutta percha had been earlier understood, it was more than probable that wires suspended in the air would never have been tried. In Prussia it was currently stated, that during the political disturbances, the over-ground wires were twenty times destroyed by the populace, whilst those which were under-ground were only once, or twice injured. The posts also were repeatedly split by the action of lightning, and even guard-houses had been burned.

With reference to the two papers before the Institution he must observe, that they had omitted to mention several very useful instruments. He would instance one in particular, which from its intrinsic merit demanded full description. He alluded to the invention of Dr. Dujardin, of Lille, which was so compact, that the apparatus necessary for working a series of telegraphs over four hundred miles was contained in a moderate sized box.

The instrument consisted of a magneto-electric apparatus, by means of which an electric current was transmitted from one station to another, and bringing a pen into contact with an endless strip of paper, making a dot, or series of dots, part of a symbolic alphabet previously arranged. Audible signals could also be given by the same instrument, by blows against a bell, by a hammer, carried upon the armature.¹

Lieut. JULIUS ROBERTS, R.M.A., objected to the evident difficulty of detecting the precise spot of any failure in the underground wires, and the prejudicial effect of the communication being arrested for any length of time, as telegraphic messages had now become almost indispensable for all monetary and commercial transactions. It was also necessary to ascertain, even if the gutta percha covered wire

¹ In an anonymous and undated description of this instrument, published at Lille, it is thus described:—"Le télégraphe électrique, que nous allons décrire, fonctionne à l'aide d'un fil; il écrit les dépêches au moyen d'une pile, ou sans pile. Dans le premier cas, nous employons, pour le faire fonctionner, un instrument que nous appelons '*manipulateur*,' et dans le second, nous employons une machine magnéto-électrique."—EDITOR.

was enveloped in lead, whether the admixture of any foreign matter with the lead, which was by no means unusual, would not induce a galvanic action which might neutralise the effect of the insulation.

Mr. C. W. SIEMENS explained, that by means of very delicate galvanometers, it was found practicable to ascertain, at the testing points, very nearly the spot where any defect existed, and the opening the ground and repairing the leak seldom occasioned any practical inconvenience.

Mr. E. CLARK explained, that any galvanic action in the lead covering would not affect the wire, when thoroughly covered with gutta percha, in which state it became virtually a Leyden jar, charged with galvanic fluid; and, practically, it was found to retain a charge, for some minutes after contact with the battery had been broken; there were, however, to be apprehended, other causes of objection to the lead covering, which he was then examining into and which he apprehended would induce its rejection, for underground wires.

Mr. BIDDER said he was the first to adopt the electric telegraph practically, by giving it a trial on the Blackwall Railway; the method of insulation in that instance was very imperfect, and the current was liable to frequent interruption, from the water leaking into the pipes, in which the wires were laid. It was next applied to the Norfolk Railway, where, although there were several double and single lines in conjunction with it, the working of the system was very perfect, considering the early period of its execution. The facilities offered for working railways, and the commercial advantages afforded by such a rapid means of communication, were too self-evident to be overlooked, and the formation of the Electric Telegraph Company was the natural consequence. One of the first questions considered was the mode of placing the communicating wires, and after careful deliberation and experiment, the overground, or suspended system was decided upon. The latter plan was adopted, because of the limited knowledge, then possessed, of the means of insulation, though it was, even then, well ascertained that the wires, if placed under ground, would require to be protected by a casing of some durable substance over the gutta percha, which, at that early period of its introduction, was not so well manipulated as at present; besides which it could not be then known how many wires would be required. The expense also somewhat influenced the decision, as the under-ground system was estimated to cost about £35 per mile, for each wire, whereas the suspension system was found to cost only about half that amount. If then the proceedings of the Company had to be recommenced, *de novo*, it was evident that no other sound decision could be arrived at. Now it was discovered,

that there were certain situations, where the under-ground system could be advantageously employed; there were more perfect methods of insulation, and greater facilities for detecting defective communication; all these had been adopted with success, yet the suspended system was still generally used. Even in that mode of communication, which appeared to be so very simple, there were considerable difficulties to contend with; the atmospheric influences, the condensation of fog on the wires and in the cups of the insulators, the deposition of carbon from smoke and of coal dust, in certain districts, all tended to injure the insulation; to that point, therefore, constant attention had been directed, and Mr. Edwin Clark and others had done much towards attaining perfection; still daily experience demonstrated how much yet remained to be discovered of the theory and of the practice. However, in spite of all the difficulties the telegraphic communication was maintained with few interruptions and with great benefit to the public; and without the telegraph, it was almost impossible to manage the railway traffic of the present period.

With respect to the instruments used, the main points were simplicity of construction, rapidity and precision of action, and the facility of being easily understood. On these accounts the needle instruments were still adhered to, and with experienced readers, a great quantity of work could be done very rapidly; Mr. Bain's instrument, improved by Mr. Latimer Clark, had been used, and three hundred words per minute had been transmitted by it, with perfect secrecy; but the ordinary needle instruments were better adapted for general purposes. The inventive faculties appeared to be inexhaustible, with regard to new electric telegraph instruments; in fact, any ingenious clockmaker could produce modifications of them, and the ink on the receipt for the purchase of one would scarcely be dry, before another, perhaps better and cleverer, would be offered from the same fertile source.

The extent to which the electric telegraph was employed in the United States and on the Continent, had been alluded to, but Mr. Bidder believed, that if the capabilities for transmission were not infinitely greater in this country than elsewhere, the present wants of the public would not be satisfied. The rapidity of railway transit demanded corresponding velocity of transmission of communications, and would eventually necessitate telegraphic connection with the remotest portions of the globe.

He would not pretend to enter into the statistics of telegraphic communication, but he might state, that about fifty-six thousand messages per month were transmitted, and the contents of a closely-

printed octavo volume emanated in messages daily, from the Central Office of the Electric Telegraph Company. The arrangements of that Company were too complicated to be described, even in the most popular manner, at a meeting of the Institution, and therefore he would only say, that great as had been the progress of the system hitherto, he believed it to be comparatively in its infancy, and it was probable, that great revolutions in the mode of working would take place, as, like the railway system, by the facilities it offered it would create the demand for its services, ingenuity would be taxed for the discovery of the means of overcoming present difficulties, and diversified as were already the objects towards which it was directed, the time would come, when individuals would correspond directly with each other, without the intervention of the clerk at the office, with perfect secrecy, and the most important affairs would be concluded without personal communication and independent of distance; already it was necessary to have a very large staff at the Central Office, ready to transmit the messages, the number of which varied with the fluctuations of commerce, or with the agitation of the political world.

A reduction in the charge for sending messages had also been made, and in spite of increased expenses, the profits of the Telegraph Company were larger; in fact considering the present state, and looking forward to what must be the future state of Great Britain and the Continent, the necessary spread of telegraphic communications was almost too vast to be calmly contemplated, and it would be felt that the system was yet but in its early infancy.

Mr. WHISHAW insisted on the importance of obtaining credible information as to the relative advantages, and disadvantages of the overground and underground systems of stretching the wires; the former system was very successful in Prussia, and the difficulties experienced, had arisen from defects, which when discovered, were easily remedied: as for instance, the insulation had been destroyed by vermin gnawing the covering of the wires, which was of gutta percha, without further protection; when an outer coating of lead was added, no further annoyance was experienced.

He objected to the overground, or suspended system; it was frequently out of order; was liable to be affected by lightning; the posts were dangerous, if they fell down on the lines owing to trains running off the rails; and in a railway accident it was not improbable, that just at the time when the telegraph was most required, it would be found to be out of order, in consequence of the posts having been knocked down by the engine, or carriages, on the occurrence of the accident.

The needle telegraph might be a sufficiently good instrument, but he could not admit that it was the best; the only really good instrument was that which could be worked by any person of ordinary ability without previous practice; the time required for educating a person to work the needle instrument was one of its greatest defects, and would eventually cause it to be superseded by some simpler contrivance.

Mr. BRUNEL, V.P., could not permit the statement to be received as correct, that accidents were likely to arise from the falling of the posts upon the line, or that the communication was liable to be interrupted by the posts being knocked down by the engines, or carriages. He had only heard of one such accident, which occurred soon after the first establishing of the overground, or suspension system on the Great Western Railway; on that occasion, one post had certainly been knocked down by an engine running off the rails, but he believed that was almost a solitary instance, and if the posts were placed with any judgment, there was but little chance of the repetition of such an accident. The wires were originally laid under ground, but the expense of keeping them in order was so great, as to induce the abandonment of the system; still there were situations where, and circumstances under which, it might be advantageous to have recourse to that system, and he conceived it was practicable to guard against, or remedy the defects, which had hitherto been alleged to exist. The suspension system presented greater facilities for repair, than could be offered by any other plan, and even fully admitting all the alleged objections against it, he thought that for all ordinary purposes it would be found the simplest. Still there were localities where the under-ground system must be employed, and therefore it was necessary to attempt its improvement in every way, as well as to devise the means of remedying the effects of disruption from slips, either on embankments, or in cuttings, and providing against the dampness of the clay and other retentive soils, which militated against the system. The fact of the lightning so frequently injuring the suspended wires abroad, indicated a dry state of the atmosphere, and there would be, to a certain extent, a corresponding dryness of the soil which would be more propitious for buried wires, than the humid soil of this country. It would be very desirable to obtain an accurate statement of the experience in Prussia, as to the relative merits of the over and the under-ground systems; it had been rumoured, that peculiar effects were observed, which induced doubts as to the permanence of the insulation of the wires.

Mr. J. L. RICARDO, M.P., confirmed the previous statement; he had only heard of this one case of the falling of a post upon the line,

and then it was not clearly shown whether it was the post that threw the engine off the line, or the engine that knocked down the post.

He entertained a strong feeling in favour of the needle instruments; at the commencement of the system it was considered necessary to employ men to work the instruments, but now the Telegraph Company obtained boys from the Orphan Asylum, and it was found, that a boy must be more than ordinarily dense, if he could not manipulate the instrument perfectly well after about one week's practice.

The SECRETARY stated, that communications had been received from Mr. Doull, Assoc. Inst. C.E., and Mr. C. V. Walker, to the effect, that it was so rare an occurrence for an engine to run off the line, precisely among the telegraph posts, that such a contingency had certainly not been provided for; especially as if it did occur, the junction of the ruptured wires could be so soon effected as to cause little, or no inconvenience. In seven years the only accidents at all approaching this character were at Gravesend, where on the trial of some wide carriages a shed was knocked down, and at Charlton, when a train was thrown off the rails; in both cases the wires were ruptured, but the damage was repaired and the circuit, restored, within a few hours after the workmen reached the spot.

Mr. WALKER preferred the suspended system for ordinary positions, as being less costly, and affording more ready access for repairs. The under-ground system must be used in certain situations liable to defective insulation, such as in tunnels,—by the sea-side,—in the neighbourhood of large towns,—traversing a mineral district, where the air was loaded with carbon,—and of course for subaqueous communication.

Mr. C. W. SIEMENS said it must not be assumed, that a slip would seriously affect an under-ground wire, as 5 per cent. of slack wire was left expressly to allow for such a contingency. The buried wires had been found to suffer most in dry sandy soils, partly from the attacks of the field rat, and partly from the influence of the air, which penetrated through the soil. He did not believe, that wet would affect gutta serena. The art of working the instruments, in Prussia, was found to be easily acquired, and after a little practice the manipulator worked the instrument with his left hand, whilst he wrote with the right; the same system was, he believed, now followed in England.

He thought that the wires covered with gutta serena and lead, could be made perfectly secure and would be, in the end, more economical than the suspended system.

Mr. BIDDER objected to a comparison of the relative expense of the two systems being deduced from the use of an imperfectly insu-

lated wire, for the under-ground plan ; if, as was proved to be necessary, the wire was covered with lead, over the gutta percha, each wire would cost £35 per mile, which would amount in many cases, to a prohibition for laying down the wires in this country.

Mr. STATHAM said he could produce a perfectly insulated wire, coated with gutta percha, and covered with lead for much less than £35 per mile. He was not aware of any instance of rats destroying gutta percha ; but on the contrary, in manufactories, where great annoyance had been experienced from the vermin nibbling the gut-bands, it had been found, that on adopting gutta percha, all inconvenience of that kind was got rid of. The defective insulation complained of, had generally arisen from badly made connections, where a certain amount of moisture could enter. The success of the submarine wire confirmed his statement, and if the covering was carefully performed, the insulation could be rendered perfect. He had fired gunpowder through a coil of two hundred and forty miles of insulated wire, laid under water.

Mr. BRETT, in answer to questions, said the cost of the submarine cable from Dover to the coast of France was about £500 per mile. The covering of the core cost about £56 per ton. The cable between Dover and Ostend contained six insulated wires ; it was capable of being coiled into the hold of a vessel. The largest sized cable, yet used, could be "payed out" from the hold, in one length of sixty to seventy miles, and there was no difficulty in making the joints at sea, in fine weather.

Mr. L. CLARKE described an application of the electric telegraph to railway semaphores. The apparatus consisted of a Bréguet's differential thermometer, composed of a coil of two different metals, which expanded unequally under heat ; this being placed above the signal lamp, so long as the lamp was burning, the end of the coil was pressed against a stop and formed part of an electric current ; but if the lamp was extinguished the metallic coil contracted and the circuit being broken, a bell was rung, which warned the pointsman of the state of the signal lamp. Bain's printing telegraph had been tried in this country ; it was in use between Liverpool and Manchester and London. The communications made by it were slower than by means of the needle instruments ; this, however, arose chiefly from the want of a better system of punching the marks in the strips of paper, indicating letters in the instrument. Mr. Clark had endeavoured to remedy this complaint, and by a modification, had produced a punching machine, which being used in conjunction with Bain's printing instrument, would enable upwards of three thousand words to be transmitted per minute.

Mr. REID said, that by permission of the Submarine Telegraph Company he had recently tried some experiments, in transmitting messages from Dover to France, which showed how small a power of battery was required, when the insulation was perfect. His object had been, principally, to test a pair of double-needle instruments and two new batteries which he had constructed. One of these instruments was placed in the Company's office, at Dover, and the other in the French office, at Calais, with a battery to each. Two of the submarine wires were then connected with the instruments, and put in circuit with the batteries. The length of the submarine cable in the Channel was about twenty-four miles, with about five miles of land telegraph on each side. The battery which was to work this distance formed a strong contrast to that ordinarily employed, the length being only 4 inches by $1\frac{1}{2}$ deep, and the weight 1 lb. 5 oz., while the old common battery used on the lines was generally 36 inches long, $7\frac{1}{2}$ inches wide, $8\frac{1}{2}$ inches deep, and weighed 64 lbs. On connecting this miniature battery with the instrument, the signals to and from Dover and Calais were found to be quite equal to the signals usually received from the former batteries. The next experiment was for the purpose of testing an improvement in the double-needle instrument. The miniature batteries were removed from the instruments on each side of the Channel, and a piece of zinc, three-fourths of an inch square, and a piece of silver to correspond, were then introduced into the mouth of the operator, at the office in Dover, and instructions sent to do the same at Calais. The wires attached to these pieces of metal were then connected with the instruments, and by this simple means, and by the simplest of all batteries, the telegraph clerks sent several messages to and from England to France. The next experiment was similar to this, only larger pieces of zinc and of silver were introduced into the mouth of the operator. The result was an improvement of the signals. This was on the evening of Monday, March 1. The next day, the experiments were repeated with the same success. The instruments with the miniature batteries transmitted, throughout the day, all the commercial messages, prices of stock, funds, &c. It was thought, that during these operations the miniature battery would become exhausted; but on the reverse, it improved, and seemed perfectly to maintain its character. It might be anticipated that they would become more simple, more easy to understand, and Mr. Reid contended, that the instruments and batteries in ordinary use might be greatly simplified with advantage to the service.

The SECRETARY, by permission, read a description of Messrs. Shepherd and Button's submarine telegraph cable. The invention

consisted in the application, or amalgamation of the electric wires with mooring and other chains, for the purpose of protecting them from abrasion, or rupture. The copper wires were first coated with gutta percha in the usual way, and again coated either with tape, or hempen bands, which had been previously well saturated with a composition of pitch, tar, gutta percha, &c. These tapes, or bands were either wound, or plaited like a rope round the gutta percha, containing the electric wires, and the rope was again covered with the composition before mentioned. The electric wires, with their impervious covering, were then, for greater security, enclosed in a wire casing, and when so prepared, were secured by means of clasps in the angular spaces, or recesses of chains, such as were used for mooring, or anchoring ships; the links of the chains might be made of any required strength and size, and each of the angular recesses in the chain was capable of receiving from five to ten electric wires, consequently one chain was capable of protecting from four to forty, or more wires.

The second part of the invention consisted in fixing a series of testing boxes to the line of telegraph. These testing boxes were made in three, or more parts, according to the number of electric wires, with as many grooves into which the wires were conducted; in the centre of the boxes contact was made with the continuing wires, each wire was afterwards separately insulated with gutta percha in the testing box, and the separate parts were screwed together and made water-tight; the testing boxes might be placed at any suitable distances apart, and to each of them a buoy was attached, for a twofold object: first, to indicate the submarine line, and second, in case of there being any defect, by the aid of the buoy chain the testing box could be raised to the surface, unscrewed, and the defective parts ascertained, without interruption to the transmission of the telegraphic messages being carried on through the other wires, as each of the wires would be numbered in the boxes.

The third part of this invention consisted in protecting the submarine line from the beating of the waves, &c., or the abrasion on the rocky beds at the bottom of the sea. On the sea shore, as far as to low-water mark, the submarine wire was secured in cast iron tubes with vertical and horizontal flanges and attached to the shore. Below low water the wire was secured against the beating of the waves, by means of ball and socket joint tubes with side openings. Submarine communication of this description had been laid down for the Electric Telegraph Company, at Ford Station, Brighton Railway, and in placing it across the river the chain and wires, which weighed several hundred weight, were suspended, until the wires were tested

and the insulation was found to be quite perfect; the chain on all occasions taking all the strain from the electric wires.

Mr. BAKEWELL explained the action of the copying electric telegraph, which transmitted fac-similes of writing.¹ The communication to be transmitted was written on tin-foil, with a common pen, dipped in coloured varnish. Such a message might be written by a merchant in his counting-house, and be sent to the Telegraph Office to be transmitted, like a letter sent by post. The manuscript was applied to a cylinder about 6 inches in diameter, which was impelled by a train of wheels set in movement by a weight; accelerated velocity being prevented by a fan. A metal style, connected with one of the poles of the voltaic battery pressed lightly on the letters as the cylinder revolved, and by traversing on a fine screw, parallel to the cylinder, it was made to pass in succession over all the lines of writing. The receiving instrument was a counterpart of the transmitting one, and on to the cylinder of the latter instrument a piece of paper, previously moistened with an acidulated solution of prussiate of potass, was placed, to receive the message. A style of steel wire, connected with the telegraph wire from the transmitting instrument, pressed on the paper and was carried by a traversing screw-nut over its surface. The cylinder of each instrument was connected with the poles of the battery, and the styles being connected with each other, the electric circuit was completed, by passing from the metal styles to the tin-foil, on one instrument, and through the paper on the other. The electro-chemical action caused the steel point, by its deposition of iron on the prepared paper, to draw a series of blue spiral lines very close together, when the electric current was not interrupted. But the varnished writing, on the tin-foil, was continually breaking the electric circuit, as the metal style passed over the letters, and small blanks were left; the succession of which, corresponding with the forms of the letters, produced a copy of the writing which appeared nearly white, on a background of closely-drawn blue lines. It was essential to the production of this effect, that both instruments should rotate exactly together. The synchronous movement was attained by means of an electro-magnet, or magnets, brought into action by local batteries, and these magnets regulated the rotation of the cylinders, by retarding them at fixed intervals. There were several methods in which the regulating power of the magnets might be employed; either by bringing them into action at each station, by means of pendulums, or by a make-and-break-contact wheel on

¹ Vide ante, page 360.

the corresponding instrument. It was on the latter plan that the instruments exhibited to the meeting were regulated; the cylinder of the receiving instrument being frequently retarded by an electromagnet, put into action, along the connecting wire, by the transmitting instrument. In this manner, Mr. Bakewell regulated the instruments, when tried experimentally, between London and Brighton, on the wires of the Electric Telegraph Company. The rotation of the cylinder, notwithstanding the frequent retardations, was continuous; the momentary checks not being perceptible. The cylinders exhibited in action made thirty revolutions in a minute, at which rate writing was legibly copied. The rapidity of transmission by the copying process, depended much on the size of the writing and the number of times each line was passed over by the metal styles, before the operation was completed. The specimens exhibited, and which contained four hundred letters, were stated to have been copied in two minutes. To exemplify the peculiar application of this process for transmitting secret messages, an apparently blank piece of paper was shown, on which a message had been impressed invisibly, by moistening the paper with diluted acid alone; and the writing was instantly brought out, on brushing it over with a solution of prussiate of potass.

Mr. GLAISHER, through the SECRETARY, expressed his satisfaction at finding the subject of electric telegraphs so comprehensively treated, as in the Papers which had been read, and regretted that he had not the advantage of recourse to them, when drawing up his Report for Class X. of the Great Exhibition, which had been in type since last September, and which was daily expected to be issued. He directed attention to the necessity of endeavouring to lessen the cost of batteries, and mentioned Walker's graphite battery, and Lyons' battery as deserving consideration. The application of electricity, by the Americans, for astronomical purposes, was also noticed. It was stated, that by repeated experiments made on the long lines of the electric telegraph in the United States, the passage of the electric fluid was shown to have occupied a perceptible space of time, the communication being made at the rate of 12,000 miles in a second, an element that could be taken into calculation in estimating the longitude. These conclusions ought not, however, to be taken as final, because there existed a variety of disturbing causes connected with meteorology. It might also be observed, that the transmission of the electric fluid through copper and zinc wires respectively had not been as yet sufficiently experimented upon. A remarkable instance of disturbing atmospheric influence was mentioned as having occurred, on one occasion, in sending intelli-

gence from London to Norwich. In the instance alluded to, communications could be sent from Norwich to London, but not from London to Norwich. It was gratifying to state, that all the great railway companies, and the telegraph companies, had offered every facility to men of science in experimenting on the causes of these various aberrations.

Mr. A. GORDON exhibited specimens of telegraph wires enveloped in Trinidad pitch, which had been used very effectively, on the suggestion of Admiral the Earl of Dundonald;¹ this pitch could be

¹ "The pitch lake of Trinidad is situated on a promontory, at the south-west point of Trinidad at the elevation of 100 feet above the sea, and is about a league in circumference. The petroleum, or mineral pitch, has formerly flowed from the lake through a channel 2000 yards long to the beach, and there formed a promontory of 600 yards in length, projecting into the sea. A kind of natural concrete has been made, by the stream of pitch enveloping all the loose materials met with in its course, and which has for ages withstood the action of the sea: neither the atmosphere nor the tropical sun appear to affect it. It is considered, that this pitch may be used for consolidating concrete for piers, breakwaters, &c., either by using it like asphalt, by melting and mixing it with shingle, and making it up into blocks, or by other means; for repairing the foundations of piers of bridges, by dipping the stones into the melted bitumen, lowering them into the water, and ramming them into their places, from a boat moored alongside the defective pier.

"It will form also an excellent material for jointing earthenware pipes for sewerage, &c., as, by its elasticity, it will allow a certain amount of deflection, or change of form, without any fissure declaring itself. When applied to cast-iron pipes, the joints have borne a pressure of 600 feet head of water, without leakage. This experiment was tried at the works of Messrs. Simpson and Co., Pimlico, and recently at the Grand Junction Water-works. It may also be used for lining open channels, or for forming pipes, or coating the inside of tubes of any material, for the conveyance of water for the supply of towns, as the pitch does not impart the slightest smell, or taste to the water, however long a time it may rest upon it. Pipes of this material have been laid down for the supply of water to the shipping at Porta d'España.

"One of the great uses to which it might be applied is for covering electro-galvanic telegraph wires. It has been found, by decisive experiments, to be a perfect non-conductor of electricity, and from its cheapness, may be very advantageously substituted for gutta percha and other more costly materials, being much more durable, and less liable to fissures.

"A very simple apparatus has been devised for laying the electric wires thus covered. It resembles a drain-plough, from the upper and foremost part of which a tube descends obliquely towards the back; the end of the coated wire passes through this tube, and is deposited in the trench formed by the coulter of the subsoil plough.

"Numerous other uses in the arts have been tried. It constitutes an excellent japan varnish, where a glossy smooth surface is required, and it can be used to preserve timber from the attacks of marine worms, and iron from the action of sea-water, or a damp atmosphere."

Extracted from a MS. essay by Admiral the Earl of Dundonald.—EDITOR.

rendered more or less pliable as might be deemed requisite,—it was a perfect insulator, and the cost of the process of covering the wires was not one-fifth of the expense of using gutta percha.

The following extract from the recent Report on the New York Industrial Exhibition, by Mr. Whitworth, (M. Inst. C.E.) conveys some interesting information on the subject of electric telegraphs.—

EDITOR.

“ Electric Telegraphs.

“ The advantages to be derived from the adoption of the electric telegraph, have in no country been more promptly appreciated than in the United States. A system of communication that annihilates distance, was felt to be of vital importance, both politically and commercially, in a country so vast, and having a population so widely scattered. It met accordingly with great encouragement, both from the federal government, at Washington and from the local governments of the various states.

“ Distances are now to be measured by intervals, not of space, but of time: to bring Boston, New York, and Philadelphia, into instantaneous communication with New Orleans and St. Louis—to centralise in Washington at any given moment, information gathered simultaneously from the far corners of the thirty-one provinces of the union, is to extend throughout the confederacy bonds of the most intimate connection.

“ In the operations of commerce, the great capitals of the north, south, and west are moved, as it were, by a common intelligence; information respecting the state of the various markets is readily obtained, the results of consignments may be calculated almost with certainty, and sudden fluctuations in price in a great measure provided against.

“ If, on the arrival of a European mail at one of the northern ports, the news from Europe reports, that the supply of cotton, or of corn is inadequate to meet the existing demand, almost before the vessel can be moored, intelligence is spread by the electric telegraph, and the merchants and shippers of New Orleans are busied in the preparation of freights, or the cornfactors of St. Louis and Chicago, in the far west, are emptying their granaries and forwarding their contents by rail, or by canal to the Atlantic ports.

“ There may be, no doubt, similar general advantages derived everywhere, from the introduction of the electric telegraph, but they are such as affect with peculiar benefit a country like the United States, consisting of confederated provinces, differing one from

another in climate, in productions, in laws, in institutions, and in some cases in the character of their inhabitants.

“There are in the United States between twenty and thirty joint-stock electric telegraph companies, and an endeavour is now being made to amalgamate them into one company. The systems generally in use are those of Morse, Bain, and House.

“The conflicting claims of these three systems have formed the subject of protracted litigation, and without going into minute details, it may be sufficient to mention the distinctive features of each.

“Professor Morse employs receiving magnets, which close local circuits attached to each telegraph office, and so charge another magnet called the register magnet; this acts upon an armature attached to a lever, which presses down a metallic point upon a cylindrical roller; a strip of paper is passed at a uniform rate between the metal point and the roller, and by the indentation of lines and dots, representing letters of the alphabet, the message transmitted is registered at the rate of about twenty words per minute.

“It has been also found practicable to receive and understand messages by merely listening to the click of the armature, and the attendant writes down the words of the message, trusting solely to his ear for interpreting them correctly.

“The cost of a Morse register is about 40 dollars (£8).

“The system patented by Mr. Bain is called the electro-chemical telegraph.

“He employs a metal disc, carrying a prepared sheet of paper, on which lines and dots are marked, by the decomposition of a metallic point, acted upon by an electric current.

“The metal disc revolves at a uniform rate by the agency of clockwork, and the point, or pen is made to move over the paper laid on the disc in the direction of a spiral.

“No receiving magnet is necessary, and a comparatively weak current of electricity, traversing long wires, leaves instantaneously a mark upon the prepared paper.

“The system is capable of being so modified as to transmit messages with great rapidity. Spaces representing alphabetic lines and dots are punched out from a long strip of paper, called the message strip; this is passed rapidly between a cylinder and a toothed lever connected respectively with the electrodes of a battery; when the tooth of the lever falls in the spaces punched in the strip, it will be in connection with the cylinder, and close the circuit; when the paper (which, being dry, is a non-conductor) intervenes, the circuit will be broken. When the circuit is closed, the pen fixed at the

[1851-52.]

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other end of the wire will mark on the paper lines and dots, exactly corresponding to those punched out of the message strip.

"In Mr. House's system the message is printed by the telegraph instrument itself. The electric current is made to act by rapid pulsations on an 'axial magnet' that opens and closes a valve connected with a pneumatic printing machine.

"The machine, which is ably contrived, is worked by manual power, and prints messages at the rate of about twenty words per minute; its cost is about 250 dollars (£50.)

"Grove's batteries are generally used in all the systems.

"The aggregate length of the telegraph lines in the United States exceeded, in 1852, 15,000 miles, of which 12,124 were worked on the system of Morse; 1,199 on the system of Bain; and 1,358 on the system of House. These numbers have been considerably increased this year, and many amalgamations of the different companies working under Morse's and Bain's patents have been made.

"In November, 1852, eleven different companies had offices in New York.

"Extracts from the annual reports of two companies, one whose line extends from New York to Washington, in competition with a rival line; the other, a western company, whose line connects Pittsburgh with Louisville, will serve to give an idea of the amount of business carried on.

"*New York and Washington Line.*—Messages are charged at the rate of 50 cents (2s. 1d.) for ten words, and 5 cents (2½d.) for every additional word, for transmission from New York to Washington, a distance of 270 miles.

"The most distant points connected by electric telegraph in North America are Quebec and New Orleans, which are 3,000 miles apart, and the network of lines extends to the west as far as Missouri, about 500 towns and villages being provided with stations.

"There are two separate lines connecting New York with New Orleans, one running along the seaboard, the other by way of the Mississippi, each about 2,000 miles long. Messages have been transmitted from New York to New Orleans, and answers received in the space of three hours, though they had necessarily to be written several times in the course of transmission.

"When the contemplated lines connecting California with the Atlantic, and Newfoundland with the main continent, are completed, San Francisco will be in communication with St. John's, Newfoundland, which is distant from Galway but five days' passage. It is, therefore, estimated that intelligence may be conveyed from the Pacific to Europe, and *vice versâ*, in about six days.

“The cost of erecting telegraph lines varies according to localities, but the expenses, upon the whole, are estimated to average about 180 dollars (about £35) per mile throughout the States ; the moderate amount of this estimate is, in a great measure, to be attributed to the facilities afforded by the general laws for the formation of companies and for the construction of lines.

“The electric telegraph is used by all classes of society, as an ordinary method of transmitting intelligence.

“Government despatches, and messages involving the life, or death of any persons, are entitled to precedence ; next come important press communications, but the latter, if not of extraordinary interest, await their regular turn.

“The leading newspapers of New York contribute jointly towards the expenses of daily telegraphic communications. The annual sum paid by the ‘Associated Press’ averages 30,000 dollars per annum.

“Interruptions occur most frequently from the interference of atmospheric electricity : in summer they are estimated to take place, on an average, twice a-week, but many contrivances have been adopted for obviating this inconvenience, such as lightning arrestors, &c., which are generally known ; the number of interruptions have been thereby reduced about 30 per. cent.

“Other accidental causes of interruption occur irregularly, from the falling of the poles, the breaking of the wires by falling trees, and particularly in winter, from the accumulated weight of snow, or ice.

“The electric current is made to act through long distances, by using local and branch circuits, and relay magnets, in those systems where it would be otherwise too weak to operate effectually.

“In Mr. Bain’s system, a weak current is found sufficient for very long distances ; between New York and Boston, a distance of 270 miles, no branch, or local circuit is required. In some cases, where both Morse’s and Bain’s telegraphs are used, by an amalgamated company, in the same office, it is found convenient, in certain conditions of the atmosphere, to remove the wires from Morse’s instruments, and connect them with Bain’s, on which it is practicable to operate, when communication by Morse’s system is interrupted.

“It is generally believed, that by laying insulated wires underground the interruptions will be reduced, so as to be altogether inconsiderable. The expense of the process, however, is regarded as a great impediment in the United States, where cheapness of construction is an object of the highest consideration.

“The application of the electric telegraph is not confined to the transmission of messages from one part of the States to another : in

the form of a local, or municipal telegraph, it is employed as an important instrument of regulation and intelligence in the internal administration of towns. No adaptation of the system can be more interesting and useful than that which is made for the purpose of conveying signals of alarm and intelligence in the case of fire. This system has been very completely developed in Boston."

March 9 and 16, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

THE discussion upon the Papers, Nos. 863 and 867, "On the Electric Telegraph," by Mr. F. R. WINDOW and Mr. C. C. ADLEY, being renewed, was extended to such a length as to preclude the reading of any communication.

March 23, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 871. "On the Results of the use of Tubular Boilers, or of Flue Boilers of inadequate surface, or imperfect absorption of heat." By Admiral The Earl of DUNDONALD.

No. 873. "On certain Points in the Construction of Marine Boilers." By JOHN SCOTT RUSSELL, M. Inst. C.E.

No. 874. "Description of a Diaphragm Steam Boiler." By PIERRE HIPPOLYTE BOUTIGNY (d'Evreux), Assoc. Inst. C.E.¹

No. 871. "On the Results of the use of Tubular Boilers, or of Flue Boilers of inadequate surface, or imperfect absorption of heat." By Admiral The Earl of DUNDONALD, &c. &c.

AN important collateral advantage derived from science, consists in the anticipation of practical results, generally consigned by mankind to chance, or to the slow development of time—results which, when the safety of the public is endangered, demand an effort to avert the evil consequences of indolence, or neglect.

With that view, the accompanying observations on Marine

¹ The discussion on these papers was taken together, and was extended over portions of two evenings, but an abstract of the whole is given consecutively.

Boilers, are submitted to the consideration of the Institution of Civil Engineers.

The practice of the steam department of the naval service, has hitherto been to limit the boilers to the smallest dimensions, with which fire could be made to supply steam to the engines—an error, which in respect to danger is in some degree obviated, by a positive command, that in no case shall the engines be worked at full power, unless under the most pressing exigencies—to be noted in the log-book, and reported by letter to the Admiralty. This advantage does not, however, extend to the Post-office steam-packets, and even if such an order existed, there is no adequate power to enforce it.

Impressed with the importance of the subject, the Author made many representations to the naval authorities, and eventually received permission, to have the correctness of his views tested by experiment.

Trials were, accordingly, officially made at Chatham Dock-yard in 1844, on the evaporative power of boilers having vertical water tubes, contained within a chamber four times the capacity of those tubes. The products of combustion were introduced at the upper part of this chamber, and retained there; until they reached the bottom, at the opposite side, by which arrangement the vapours remained four times longer in contact with the tubes, being suspended by their levity in the upper region of the chamber, until they became cooled, when they gradually descended and escaped, at a temperature little exceeding that of boiling water.

The average excess of absorption of heat, by this boiler, was upwards of forty per cent more than that in a boiler constructed at Woolwich, with oblique fire tubes. This important fact has been recently confirmed by the pre-eminent power and economy of similar boilers used in the North American trans-Atlantic steam-packets, and also by some built for the Russian service, and placed on board the frigate "Ostragnoy," when trials were made which enabled the results to be compared with those obtained on board the "Crabroy," a similar ship, built on the same lines, having engines made from the same patterns, and both precisely alike, except in the construction of the boilers.

It is not however the merits of compactness, levity, power, or durability, to which it is at present desired to call attention, but to the fact, that during the trials of the respective boilers at Chatham and Woolwich, in 1844, the temperature of the funnel, deriving its supply from the bottom of the chamber, containing the vertical water tubes, was so low, that a handkerchief was held in it without

injury, whilst the vapour of the chimney connected with the oblique fire tubes actually melted lead.

On considering the subject, it will be seen, that no danger can possibly arise from using any quantity of fuel, which the furnaces are capable of containing, as from the form of the tube chamber, all the heat is retained, and the gases are consumed, and effectually absorbed, before they can descend to the aperture of the chimney.

Humanity seems to demand, that these facts (if doubted) should be investigated, as a probable means of averting danger, whether arising from carelessness, or want of skill, or from the rivalry of companies, contending, over thousands of miles of transatlantic navigation, for the reputation of reducing, by a few hours, voyages already accomplished in an almost incredibly short period.

The paper is illustrated by a diagram showing the peculiar construction of the heat-trap of the boiler.

No. 873. "On certain Points in the Construction of Marine Boilers." By J. SCOTT RUSSELL, M. Inst. C. E.

THOUGH during the last ten years, the whole system of boiler-making has undergone a complete revolution—the simple tubular boiler having taken the place of all older systems,—yet the illustrations now about to be adduced, in corroboration of certain principles, differing from those which were, or are generally, if at all, recognized, are some marine boilers constructed more than ten years ago for the Royal Mail Steam-Packets "Clyde," "Tay," "Tweed," and "Teviot." As they were designed for the express purpose, and with the idea of their lasting fully that length of time, it was impossible for this communication to have been made earlier, unless indeed, they had been prematurely worn out. But on the contrary, they are still doing their duty as well as ever, after having performed more, it is believed, than has ever been previously accomplished,—steaming night and day, with very little interval, during the whole of that period, and running a distance of from forty-two to forty-eight thousand miles per annum, or a distance about equal to twice round the world every year.

The main object in view, in the construction of these boilers, was durability, combined with effective combustion and economy of fuel.

The first point that was considered, as likely to be conducive to the durability of a boiler, was a judicious distribution of the most

intensely heated surfaces. It is very well known, that the heat is most intense on the sides and top of the furnaces, and diminishes thence, through the flues to the chimney. The usual practice has been to return the flues, whether tubular, or not, over the furnaces; by this means the greater heat is nearer the bottom of the boiler, and the lower temperature is nearer the surface of the water. This being, in the present case, objected to, the top of the furnaces and the hottest flues were brought to the surface of the water, and the cooler, or return flues were taken to the bottom of the water.

Many advantages were gained, or rather many disadvantages were avoided by this system. When the more intense heat is deep down in the water, it there generates bubbles of steam, which pass up over the surface of the tubes, or flues above, and thus these tubes and flues are in a mixture of steam and water, instead of water alone, to the injury both of their efficiency and durability. When, on the contrary, the greatest heat is nearer the top, the water is gradually raised in temperature as it rises; and it receives the increased temperature when and where it is most wanted, or just before it rises from the surface of the water, in the shape of steam. The water in such a boiler is pumped in below, at the cooler part of the boiler, is gradually warmed as it rises and has its final charge of greatest heat imparted to it, only at the last moment. By this means also, large bubbles of steam are prevented from accumulating in contact with the intensely heated metal, and the water is brought into perfect contact with it.

The second point of importance in the construction of these boilers, was the unusually large capacity of the furnaces, or fire-boxes, and their height above the incandescent fuel. To this may be attributed the perfect combustion and economy of the fuel, and the unusual durability of the fire-boxes. The intense heat of the furnace being radiated over a larger surface, and therefore more efficiently distributed.

The third point is the large extent of evaporating surface; tending directly to promote durability. It will be observed, that in these boilers, for every foot of furnace bar, there are 3 feet of evaporating water surface.

The last essential point is the means of blowing off. For this purpose, unusually large water spaces were provided, beneath the flues and furnaces, as reservoirs, for the collection of brine and other deposit, to which the blowing off valves were attached. That this plan has been successful is fully proved by the length of the term of service of these boilers.

The practical results arrived at, previous to the construction of

these boilers, those upon which they were designed, and which experience has established to be true, are—

1st. That marine boilers, judiciously made, will last, without material repairs, for ten years. The whole interior parts of these boilers, even those exposed to the greatest heat, having during that period, undergone no repair. A portion of the outer case of the steam chest, and a part of the outside case, at the bottom, where it was exposed to the action of the bilge-water, or was inaccessible to paint, were alone decayed and had been once repaired.

2nd. That it is better to have the greater heat near the top, than at the bottom of the water.

3rd. That it is most important to durability to have higher furnaces, or fire-boxes, than are generally used.

4th. That boilers, properly formed, may be so effectively kept clean by ordinary blowing apparatus, that during ten years constant work no damage will accrue from incrustation.

The Paper is illustrated by a diagram exhibiting the construction of the boilers.

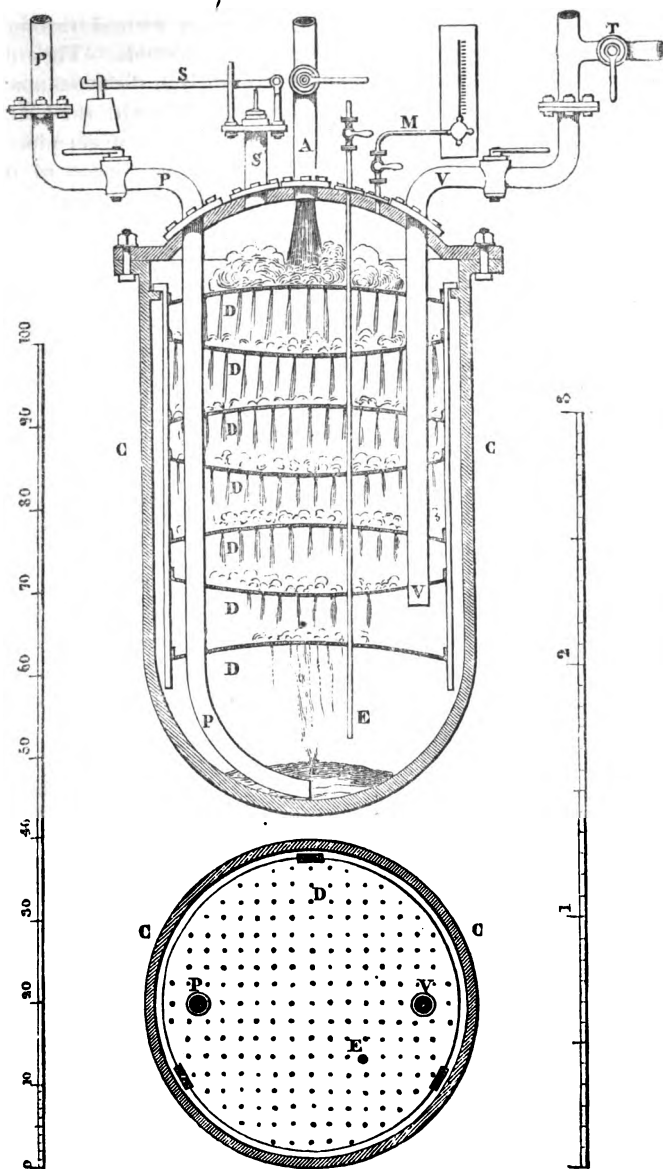
No. 874. "Description of a Diaphragm Steam Generator." By
T. HIPPOLYTE BOUTIGNY (d'Evreux), Assoc. Inst. C.E.¹

THE Author's well-known researches into the subject of water in a spheroidal state, have established the fact, that bodies evaporate only from their surfaces. This being received as an axiom, the practical result would necessarily be, that, in the construction of steam generators, the evaporating surface should be extended to the utmost limit; this has however certain objections, either of complexity of construction, additional weight of metal, greater cost, &c. The next step then was to consider, whether water could not be brought into contact with metal surfaces, so heated as to obtain the greatest amount of evaporation, with the least expenditure of fuel. An extended series of experiments demonstrated the practicability of this, and a steam generator constructed on this principle, has been for some considerable time in daily use, at the Stearine Works of Messrs. Jaillon, Moinier & C^o, Paris.

This steam generator (woodcut, Fig. 1,) consists of a vertical wrought iron cylinder, terminated at its base by a hemispherical end, and closed at the top by a curved lid, to which are attached the usual steam, safety, and vacuum valves, steam and feed pipes, waste pipe,

¹ The Author was elected Assoc. Inst. C.E., December 7th, 1852.

Fig. 1.



and other appendages. Within this cylinder are a number of wrought iron diaphragms, having their edges turned upwards, their surfaces being alternately convex and concave, and being pierced throughout with small holes countersunk from the underside. They are suspended on three vertical rods, and fixed at given distances apart, in such a manner that they shall not be in contact with the heated cylinder, or shell of the boiler. The orifice of the steam pipe is between the two lowest diaphragms, within a few inches of the bottom of the generator, so that the steam is at a high and equable temperature and in the fittest state of elasticity.

The orifice of the feed pipe being at the centre of the cover of the boiler, when the feed is turned on, the water falls upon the middle of the upper diaphragm, which, having a convex surface, has a tendency to direct towards the periphery, all the fluid which does not pass immediately through the perforations, thence it falls upon the second diaphragm, which being concave, causes the water to flow in the contrary direction, from the circumference to the centre, and thus through the entire series, dividing the water into the most minute particles, or in other words obtaining the greatest amount of evaporative surface of fluid. The whole of the water is not only kept in a state of motion, so as continually to expose new surfaces to the heat, but it must evidently be divided by the perforated diaphragms into minute columns and globules, like a shower of rain, and thus be in the best state for absorbing caloric. In fact the process of the formation of steam within this generator, must be that of the injection of a small quantity of water, into a highly heated chamber, where it is minutely subdivided, and immediately converted into highly elastic steam, without the necessity for the absolute contact of the fluid with a heated metallic surface.

The setting of the boiler is very simple; it resembles that of a common domestic brewing copper, the fire grate being beneath the hemispherical end; but in order to obtain a large surface, the flame is made to traverse a series of vertical flues, extending in spaces of 8 inches each around the entire circumference, alternately ascending and descending, until it reaches the chimney, by which time it has expended the greater part of its caloric.

The ordinary pressure, under which this boiler has been worked, is ten atmospheres, or 140 lbs. per square inch, which in round numbers is equivalent to 181° Centigrade or 358° Faht. Now as according to the experiments of Baudrimont and others, iron possesses its greatest amount of tenacity at a temperature of 200° Centigrade, it will be perceived, that although the pressure may at

first appear great, the iron is just in that state at which it can best support that degree of tension.

When the boiler is first set at work, a few pints of water are injected by a hand pump; the fire is urged, and in about twenty-five minutes there is steam to work the engine, and the ordinary feed cock is opened as the engine commences working.

It will be noted, that there should generally be a small quantity of water in the bottom of the boiler, to prevent injurious effects on the metal directly in contact with the flame, and to raise steam for starting the engine, after a temporary stoppage. Provision is also made for blowing out any deposit that may occur, by means of a pipe which descends to the bottom of the boiler.

	m.	c.
The extreme height of the boiler is	0·64	= 25 inches.
Ditto, of the cylindrical sides	0·54	= 21½ „
Diameter	0·32	= 12½ „

After deducting the surface covered by the brickwork of the setting there remains 0·55 square metre = 473 square inches of heating surface.

The actual results obtained were; that in 9 hours, there were consumed 81 kilos. = 182½ lbs. of coal, the quality of which was not good, as it scarcely gave out 6000 units of caloric per kilogramme; the quantity of water evaporated from a primary temperature of 39° Cent. = 102° Faht. was 351 kilos. = 789½ lbs. under a pressure of 10 atmospheres = 140 lbs. per square inch.

According to Morin's experiments 0·60 is the limit of useful effect to be reckoned upon, even in the best furnaces, but engineers are generally content to take 0·50. Adopting that figure as the basis of calculation, the result obtained from this steam generator would be

$$81 \times 6000 \times 0\cdot50 = 243000.$$

Examining then the amount of caloric contained in 351 kilos. of water evaporated under a pressure of 10 atmospheres.

$$351 (550 + t - t') = 242892 \text{ caloric.}$$

$$\text{In the above formula } t = + 181^{\circ} \text{ Cent.}$$

$$t' = + 39^{\circ} \text{ Cent.}$$

$$\text{Therefore caloric produced} = 243000$$

$$\text{Ditto absorbed} = 242892$$

$$\text{Ditto lost} = \underline{\underline{108}}$$

This result is not given as the limit of what may be obtained, as the Author is well aware of many defects of construction in the generator; but he submits, that enough has been done to point out certain advantages, which Engineers will not be slow in availing themselves of, if on examination the system be found practically advantageous.

The chief merits of this steam generator would appear to be simplicity of construction and of setting; the limited dimensions; the rapid production of steam at a high degree of elasticity and dryness; the economy of fuel; and the almost entire absence of danger of explosion.

It has been generally admitted, that the most fertile cause of explosion has been the sudden formation of a large quantity of highly elastic steam, from the injection of water upon intensely heated parts of a boiler. Now in this generator it would be impossible to heat the diaphragms beyond a given degree, because they are not in contact with the exterior shell of the generator; and any water introduced, must come first into contact with the diaphragms, and before any of it could reach the bottom of the boiler, even supposing that part to be red hot, the whole would be converted into steam, the equilibrium would be restored, and thus all danger would be obviated. This will be more readily appreciated, by remembering the vast amount of latent heat in steam, and how feeble is the property of iron for retaining caloric.

Supposing, however, that the hemispherical end of the generator should become red hot, and the temperature = 500° Cent.; the mass of metal heated being presumed to weigh 10 kilos., it is easy with these simple data to determine, by the following expression, the amount of caloric contained in that part of the generator.

$$\begin{array}{rcl}
 m \ c \ t & = & \text{Caloric} \\
 \text{Let } m \text{ represent the mass} & = & 10 \text{ kilos.} \\
 c \text{ the capacity of the iron} & = & 0.12 \\
 \text{and } t \text{ the temperature} & = & 500^{\circ} \text{ Cent.}
 \end{array}$$

then $500 \times 0.12 \times 10 = 600$ units of caloric, which is the precise quantity required to convert a kilogramme of water into steam, supposing the primary temperature of the water to have been = 50° Cent. Therefore one kilogramme of water would suffice to restore the boiler to its normal state of temperature.

The Author is aware, that there may be many practical objections urged against the application of this system to large boilers, and in fact, up to the present time, it has only been tried on a small scale and with the intention of providing for the peculiar

wants of those who require a motive power, but whose premises are generally ill adapted to afford the necessary space for a steam boiler of the ordinary construction. The boiler which has been described, supplies steam for an engine of 2 H. P. and occupies a space of 3 feet 3 inches diameter by about 4 feet in height, including the brickwork.

Numerous modifications will assuredly be suggested, by the practical engineers to whom this boiler is submitted, and to whose candid consideration the Author commits a system, which he trusts may eventually be found as useful in practice, as he feels certain it is correct in theory.

The paper is illustrated by a diagram from which the wood-cut, Fig. 1, (presented by the Author,) is compiled.

MR. A. MURRAY said Lord Dundonald had scarcely done justice to the principle he advocated, as demonstrated by the results of the comparative experiments on the evaporative power of some tubular boilers, made at Woolwich, and the vertical tubular boiler of the 'Janus,' the statement of which had been published and was appended to the paper before the Institution.¹ As far as the absolute evaporative power went, the boilers of the 'Janus' gave better results than any other marine boilers, although not so good as long Cornish boilers. Still it was necessary to consider the practical advantages and disadvantages of the horizontal and vertical tubular boilers as compared with those on the old flue system, and whether any great economy of fuel resulted from very slow combustion. Some experiments made at the dockyards showed, that as good evaporative effect was produced by burning the same quantity of fuel, in the same time, in three furnaces of a boiler, as had been previously obtained with four furnaces. In marine boilers there were many points to be considered besides the mere evaporative power and economical working.

The durability, alluded to in Mr. Scott Russell's paper was an important feature; in the case of the boiler on board the West India Royal Mail Packets, their duration might be attributed to the large heating surface,—1 foot of grate to 3 feet of water surface; this was more than could be allowed for boilers on board steamers in the Royal Navy.

¹ Vide Appendix to Lord Dundonald's Paper, No. 871—a printed document, containing "Result of Experiments made on the Evaporating power of Marine Boilers."

The views of Mr. Scott Russell and M. Boutigny were diametrically opposed to each other; the former were now considered somewhat antiquated for the present demand for speed and compactness of space, and the latter would be hazardous on board vessels where there was always more, or less danger from a highly-heated dry surface of metal.

Dr. FARADAY said Mr. Boutigny's proposition was interesting, as a theory, and viewed in that light only, there could be no doubt of the rapidity with which steam would be given out, from water injected into a heated recipient, falling on and through a series of pierced diaphragms, and thus becoming a shower of minute globules whose cohesive property was entirely destroyed. The extent of evaporative surface so produced, in accordance with M. Boutigny's well-known investigations, would be very advantageous for the rapid production of steam, at a high temperature, and he imagined there would not be more danger in its production by this process, than by a slower evaporation, always presuming the boiler to be of adequate strength. The small dimensions of the boiler appeared to be in its favour for certain uses, and though he could not perceive, so well as an engineer, its practical advantages, or disadvantages, he saw as much as induced a favourable impression in his mind with respect to it.

The explosions of boilers were frequently attributed to the sudden development of a volume of steam of high density; whereas in reality there were generally some concomitant circumstances, which were not considered, because they were not observed. It was a common thing also, to refer such accidents to the decomposition of water and the production of hydrogen gas; now he had never been able to trace either one, or the other, and he thought the idea a complete fallacy, liable to divert the investigator from the real causes of such casualties.

M. BOUTIGNY said his investigations had convinced him of the correctness of the theory, and as he considered that difficulties, like dangers, were more than half overcome by looking at them with confidence, he had trenched on the province of the practical engineer and had designed this boiler with the express view of so minutely subdividing the injected water, that it should be rapidly converted into steam of high density, without ever coming into contact with the heated periphery. This object he believed had been attained, and though the boiler was but ill made, still the results were such as to warrant him in feeling confidence in the practical advantages of the system.

Mr. GLYNN said the peculiar theory propounded by M. Boutigny,

and which had been discussed at the meetings of the British Association, had induced more correct opinions as to the causes of the explosions of steam boilers. It was true they might be generally traced to the sudden production of a large volume of steam, by the injection upon, or bringing into contact of a body of water, with over-heated boiler plates; but there were other circumstances to account for the mere casualty—such as carelessness, in allowing the feed to be discontinued, and other causes, all of which sufficed to account for the accident, and which should be considered in examining into accidental explosions.

Mr. W. G. ARMSTRONG was led by the consideration of the theory of M. Boutigny's boiler, to recur to some investigations he had made on the explosions of boilers, which he would at a future time endeavour to communicate to the Institution.

In some experiments on a small scale, with a boiler with vertical tubes, he had succeeded in so completely extracting the caloric from the fuel, that the temperature in the chimney was scarcely high enough to keep up the draught. A blue flame in the chimney showed the presence of carbonic oxide, and demonstrated that there was imperfect combustion in the grate; if a larger space had been left above the incandescent fuel so as to admit a larger dose of oxygen, the combustion would have been more perfect and more economical.

Mr. A. GORDON believed that in a steam boiler with the steam up, each molecule of heat was charged with elastic vapour and ready to burst into steam, on the starting of the engine, or other sudden emission of the vapour. Thus priming frequently took place, and when the safety-valves were too small, or were otherwise unable to relieve the pressure, explosions occurred. The smaller the quantity of water in a boiler, the greater would be the amount of security from explosion. It was still a question whether the newly-introduced tubular boilers were commercially preferable to the old flue boilers; although in certain vessels the former were indispensable.

Lord Dundonald's boilers were understood to have been very successful on board some Russian vessels, and the principle demanded investigation; the same might be said of M. Boutigny's boiler, which was something like the mercury boiler, introduced by Messrs. M'Curdie and Howard, which had great evaporative powers, but which failed because the mercury could not be kept from leaking out of the boiler.

Mr. A. MURRAY thought, that sufficient attention had not been paid practically to the combustion of fuel under boilers, and to the absorption of caloric. Theoretically, it was known that a given

weight of fuel, whether consumed slowly or rapidly, ought to produce identical results, in the evaporation of water; but in practice the question of the absorption of caloric by the metal surfaces, with which the incandescent gases were brought into contact, must be considered, and it was to that particular point, the attention of practical men should be directed. Experiment would soon determine, whether a large body of ignited gaseous products travelling slowly, or a number of minutely-divided streams, or films of gas, passing rapidly over the surface of the metal vessel containing the water, would produce the most efficacious results. Hitherto in the best marine boilers only 10 lbs., or 11 lbs. of water had been evaporated by 1 lb of coal; the question was, what had been the best result in locomotive boilers, with their known rapidity of draught?

Mr. R. STEPHENSON, M.P., V.P., thought the question of the combustion of fuel under boilers was unnecessarily enveloped in doubt, and after the elaborate experiments of Sir H. de la Bèche and Dr. Lyon Playfair,¹ as well as the statements of numerous practical engineers, should have left no ambiguity on the subject. In general terms, the matter resolved itself into determining by what means the most perfect and practically economical absorption of the caloric evolved from the fuel could be effected. The slow absorption, by means of the long Cornish boiler, appeared to be the most efficient; but in certain situations that form was not available; the tubular boiler, with a rapid combustion, was therefore introduced, with the object of so dividing the mass of water into thin films, and so extending the flue surface, as to obtain good evaporative results. Still time appeared to be an element, and the gases reached the chimney at a higher temperature, than from the Cornish boiler; there were instances of such extension of the flues of those boilers, that the smoke would scarcely ascend the chimney. Now chemically a given quantity of heat was evolved by the combustion of a certain weight of fuel, and it was by the greater, or less absorption of this heat, that the merit of boilers could be tested. In marine boilers where a reduction of space and weight was essential, the tubular system appeared to be indispensable; but the results could only be attained at the expense of the durability of the metal.

The temperature at which the fuel was consumed was an important consideration; under certain conditions all the carbonic

¹ Vide "Report on the Coals suited to the Steam Navy." By Sir H. De la Bèche and Dr. Lyon Playfair. London, 1848.

oxide was not consumed in the flues, and there was not any available method of bringing a portion back again, as was practised in iron furnaces, by gathering the unconsumed gases at the tunnel-head and using them as fuel for numerous purposes. It appeared then, that with slow combustion it was not compatible to absorb all the caloric and to burn all the carbonic oxide; whereas in a locomotive boiler, where the combustion was very rapid, the quantity of unconsumed carbonic oxide was very small. Still it had only been practicable to evaporate from 8 lbs. to 10 lbs. of water with 1 lb. of fuel, even by lengthening the locomotive boilers to such an extent that the temperature in the chimney was only about 410° Fahr. whilst that of the steam was 300° Fahr. Mr. Parkes' reported having attained an evaporation of 11·72 lbs. of water.

With respect to M. Boutigny's proposed boiler, although there might not be any absolute danger, the advantages of evaporating water upon red-hot plates, were not evident. The investigations into the spheroidal theory of fluids, at very high temperatures, demonstrated that the evaporation of a fluid from a given surface of red-hot metal, was not so perfect as that from a lower temperature. The chief merits of the boiler, then, must be sought for in the advantages it offered by its compactness of form, and its adaptability to positions where only very small motive power was required. The durability of a boiler, worked at a red heat, might however be questioned, and practically it could not be viewed favourably.

The actual durability of the boilers described by Mr. Scott Russell, spoke loudly in favour of the system adopted, but the tubular form offered such important advantages for marine boilers, that a return to the old system of extended flat flues was very doubtful; and moreover, practical ameliorations in the arrangement of tubular boilers would doubtless be introduced, as greater experience of their working was obtained.

The heat trap of Lord Dundonald's boiler appeared advantageous, if time could be given, or its equivalent, evaporating surface, could be adequately provided for the imprisoned heat to act upon. Theoretically, a given area of surface, at a given temperature would only evaporate a given quantity of water in a given time; any practical change of result must be obtained by an alteration of the temperature, or of the time allowed, and in this mainly consisted the asserted differences of result obtained by slow, or rapid combustion; it was however shown by numerous experiments, that nearly as good results had been obtained in the locomotive boiler, with its rapid combustion, as by the slow consumption of the fuel under the Cornish boilers, and it was very probable, that further

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experience of the tubular system would induce modifications of form, or of proportions, by which even better results would be obtained.

Mr. BRUNEL, V.P., said there were many circumstances conducing to the more perfect combustion of the fuel, in the firebox of a locomotive, at one time than another; when, in fact, there appeared to be a greater amount of caloric evolved; for instance, at the end of a long journey, when there was an intense heat in the fire-box, and the mass of fuel on the bars was thin; although more water was being pumped into the boiler, the steam was given out in greater volume and more rapidly. This was, however, easily accounted for; a larger quantity of oxygen passed through the bars, and the incandescent fuel was mingled more intimately with the gases evolved and more rapid evaporation was the evident consequence. If a fire-box could always be maintained in that favourable condition, more economy of fuel could be practically obtained.

Mr. C. MAY must contend for the admission of the fact, that carbon, on uniting with oxygen, in the process of combustion, produced an absolute amount of heat, as certainly as a given weight of sulphur would produce only a given amount of sulphuric acid. The phenomenon of the rapid production of steam, by the thin fire, was doubtless owing to the more perfect conversion of the carbon into carbonic acid, *i.e.* the union of the carbon with its maximum of oxygen,—whereas, in a thick fire, the carbonic acid, generated by the lower stratum of the burning fuel, was probably converted into carbonic oxide, in its upward passage, and unless means were provided for admitting air above the incandescent mass, the carbonic oxide would pass through the tubes unconsumed, and would occasion loss of fuel; so under an ordinary stationary boiler, where dense black smoke, or solid carbon, was evolved from the chimney, if some provision was made for the admission of air at the back of the fire, through the bridge, or otherwise, a fresh dose of oxygen was administered to the gases, and all appearance of opaque smoke vanished. This was the foundation, of the systems of Mr. C. Wye Williams and many others for preventing smoke. It became then a question, whether it would not be advantageous to admit air to the upper part of the fire-box of a locomotive boiler, for as complete combustion consisted in converting the whole of the carbon of the fuel into carbonic acid, which could only be accomplished by the mingling with it of a certain quantity of oxygen, if any part of the gases passed up the chimney in the shape of carbonic oxide, rather more than half the practical effect of that portion of carbon must be lost, as the heat evolved by the conversion of carbon

into simple oxide was rather less than that which was evolved by the conversion of the oxide into acid ; thus the theory of definite proportion received an illustration, by the instance of the thin fire in the locomotive.

Dr. FARADAY said carbonic oxide took up two parts of oxygen for its combustion, and when that dose was given, premising it to be at a proper part of the fire-place, or flue, and there was an adequate evaporative area of boiler to pass over, the best effects (theoretically) should be anticipated. It was evident, that all the carbonic oxide passing away unmingled and uninflamed was partially lost, even although it did pass through the flues in a heated state.

Mr. A. MURRAY said the carbonic oxide rising with the carbonic acid, unless supplied with a larger dose than ordinary of oxygen, to support combustion, would be prejudicial to evaporation. The high fire-box would therefore be advantageous, as promoting a more perfect mingling of the gases, and a provision for the admission of the oxygen above the fuel might be tried.

Mr. J. SCOTT RUSSELL was an advocate for retaining the gaseous products above the incandescent fuel, and there administering the proper dose of oxygen, so that the carbonic oxide should only pass through the flues at its most advantageous temperature ; this was the theoretical perfection, and engineers had only to direct their attention to arriving practically at, as nearly as possible, that result, whether by means of flat flues, or by multitubular boilers. If the fire-box was low, besides not affording space for the mingling of the gases, the top plates were liable to be burned, and as a general rule, for marine boilers working with salt water, he thought it disadvantageous to have an intense heat low down the flues, and where the feed-water first entered. The better system was to pump in the feed-water near to the bottom, so that it should gradually receive successive increments of heat, and then having arrived at the top, should be flashed into steam at a high temperature, without any descending currents to check its regular course. This could only be accomplished by having the hottest surface at the upper part of the boiler. That this system could be carried into execution, was demonstrated by the boilers he had described, in which there had been attained a high degree of evaporative power, with economy of fuel,—great durability, and a freedom from incrustation,—by affording facility for blowing off the brine, at intervals of four hours, from the bottom of the boiler, where being at a low temperature, all deposit naturally settled. There was also a singular absence of all tendency towards priming, which he attributed to the regular rising upward of the water as it absorbed heat ;

for he had observed that in boilers, where there was any intensity of heat at, or near the bottom, and in some with vertical tubes, the whole mass of water was in a state of effervescence, and the steam was always surcharged with water. He attributed this to the counter currents in the boiler, on account of want of attention to the points he had endeavoured to enforce.

Mr. R. HUNT, through the SECRETARY, expressed his belief in there being more sound philosophy in the theory of the diaphragm boiler, than would perhaps be generally admitted. Monsieur Boutigny attributed the spheroidal state to the repulsive action of heat; others stated it to be due to a stratum of vapour, between the globule of water and the glowing capsule; but it must be remembered, that the spheroid never attained a temperature equal to 200° Fahr., and that the escaping vapour had a very much higher temperature. This vapour should have communicated much heat to the spheroid,—which, practically, was not the case. Where calorific repulsion was assumed in explanation of the phenomenon, it must not be overlooked, that fluids would not flow through the meshes of metal gauze, or through the spaces of spirally-coiled wire, when heated to redness. Perkins' experiments with heated iron shells, &c., were cases in point.

Monsieur Boutigny appeared to infer, that since the vapour was of such an elevated temperature, it would, by its tension, prove more effective than ordinary steam. This was, however, doubtful; although the dryness of the steam, and the absence of priming were favourable practical considerations. It was evident there were new conditions of the laws of calorific action, still undeveloped, and which well merited careful examination.

Monsieur BOUTIGNY (d'Evreux) begged to explain, that Mr. John Manby (Assoc. Inst. C. E.) had recently examined the diaphragm steam generators, at the works of Messrs. Jaillon, Moinier and Co., at Paris, and had completely verified the statements made in the Paper. He stated that the engine, to which the boiler was attached, was of indifferent workmanship, and evidently consumed more than its proper quantity of steam, yet the cylinder of 0 m. 14 c. = 5½ inches diameter, and 0 m. 45 c. = 17½ inches stroke, was amply supplied with steam when making 28 strokes per minute. The rate of evaporation was 351 kilos. = 790 lbs. of water, by 81 kilos. = 182 lbs. of coal in 9 hours. The pressure of steam kept up was about 7½ atmospheres = 110 lbs. per inch. The deposit was stated to be easily disposed of, and the Engineer who worked the boiler gave a decidedly favourable account of its performance, and of the little attention it required.

Monsieur Boutigny added, that he was not, at present, sanguine as to the adaptation of the system for large boilers, but it would be found very advantageous for engines of small power, and he was confident as to its safety.

Mr. HAWKSLEY had thought there remained but little to say, as to the theory of the evaporation in steam boilers, or of the best conditions for the combustion of the fuel in the furnaces, and of the gases in the flues, or of the temperature in the chimney. When air was freely admitted at proper parts of the furnace, the most elevated temperature was obtained, the incandescent gases were retained in contact with the boiler a sufficient length of time, to impart the heat to the water, and the temperature in the chimney was no higher than provided sufficient draught; thus the best conditions were practically attained. Circumstances, however, interfered with this perfection; for instance, under retorts for producing gas, three-fifths of the heated air were wasted, because the heat required by the retort, for the rapid distillation of the gas, was such that nearly all the gases evolved in the furnace and the latent heat were practically lost.

In experiments on the consumption of fuel under land boilers, he had found the temperature in the chimney varying between 600° and 700° Fahr., and under these circumstances not less than one-third of the gaseous products were escaping unconsumed. When the temperature in the furnace was 1200° to 1400° Fahr., one-half of the evolved heat might be assumed as being taken up by the water, and the other half was uselessly thrown away, except as a means of obtaining draught. In locomotive boilers there was not unfrequently a temperature of 3000° Fahr. in the fire-box, whilst that of the chimney did not exceed 600° Fahr.; in such cases five-sixths of the products were usefully employed, and only one-sixth was lost. In well-proportioned locomotive boilers, the combustion appeared to be as perfect, and the evaporation, although so rapid, to be as economical as in any other boilers, however slow the rate of combustion. Watt determined that 1 lb. of coal would practically evaporate $8\frac{1}{2}$ lbs. of water; now however 10 lbs. of water had been vaporized under favourable circumstances by that weight of ordinary fuel.

The theoretical object, in admitting air above the fuel, was to furnish oxygen for inflaming the gases; but practically Mr. Hawksley had not found any advantage to arise from the proceeding, as by interposing a layer of cold air between the heated gases and the bottom of the boiler there not unfrequently resulted a loss of 10, or 15 per cent. This, however, probably arose, either from some undue

proportioning of the atoms of oxygen and of carbonic oxide, or from the former not being so admitted as to be sufficiently intimately mixed with the latter; and therein consisted one of the principal practical difficulties; as time being an element, and a certain period being apparently necessary for the proper commingling of the admitted air and the gases, the former generally entering cold and in a body, cooled down the flues and injured the evaporative power; indeed, he thought it was scarcely possible to inflame the carbonic oxide, or to prevent the appearance of opaque smoke, without some loss of evaporative power, to be compensated for in some other manner.

Mr. BIDDER contended for the generally received law of the quantity of heat, evolved by fuel in a state of perfect combustion, being specific.¹ The practical question then was, to develop the best method of employing the products of that combustion with the least waste; *i. e.*, the most efficient mode of extracting from the heated gaseous products the utmost amount of caloric?

Apart from the mere production of steam, there were, however, many practical considerations, such as space, weight, &c., to be taken into account; in locomotive boilers slow combustion was impossible, therefore the area of evaporating surface was extended to the utmost practicable limit, in order to absorb the greatest amount of heat travelling so rapidly over it. The results were very remarkable, for as much water appeared to be evaporated as under boilers with a slow rate of combustion.

During the agitation of the gauge question some curious facts were elicited. One might be mentioned;* the boiler of a goods engine when drawing a load of 300 to 400 tons, at a speed of about 18 miles per hour, evaporated 7 lbs. of water per lb. of coke; but the boiler of the same class of engine, when running with a passenger train, at nearly 50 miles per hour, evaporated 9 lbs. of water per lb. of coke. The reason of this was evident; the speed of the goods engine was such as only to give an intermittent action of the blast pipe; whereas with the greater velocity of the passenger engine, there was a more consecutive action of the blast pipe, by which better draught was established, and more intense heat and more perfect combustion of the fuel ensued; in fact, it demonstrated, that the power of evaporation was directly, or nearly so, as the power of the blast, or as the number of strokes per minute and the volume of that blast.

¹ Vide Pole, "On the Cornish Engine." Part III. London. 1848. Art. 284.

² Vide "Minutes of Evidence taken before the Commissioners appointed to Inquire into the Gauge of Railways. 1846." Page 277.

Mr. HOMERSHAM was of opinion, that a loss of evaporative power almost always followed any attempt to introduce air above the fire. In a locomotive boiler, the comparatively restricted surface was required to do as much work as the more extended surface of stationary boilers; therefore it was necessary to adopt the blast pipe, for creating the draught in the chimney; in any attempt further to reduce the dimensions and weight of marine boilers, it would probably be necessary to have recourse to the blast pipe in the chimney, if any attempt was to be made to rival the powers of the locomotive boiler, as it was by the volume of air drawn through the fuel in the fire box, by the action of the blast pipe, that the extraordinary work of the locomotive boiler was due. Stationary boilers were clothed to prevent radiation, but the locomotive attained nearly the same end, by presenting such a restricted radiating surface. The whole question was extremely interesting to practical men, and with such ample means at the command of members, it was to be hoped some accounts of results actually obtained would be laid before the meetings every session.

March 30, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 869. "An Account of the Drainage of the Town of Richmond, Surrey, under the authority of the Metropolitan Commissioners of Sewers, in 1851." By GEORGE DONALDSON, Assoc. Inst. C.E.¹

IN consequence of applications made by the inhabitants of Richmond to the Metropolitan Commissioners of Sewers as to the insufficient drainage of the town, the Author was instructed to examine into, and report upon it. The works consequent upon his report, which was presented to the Commissioners in August 1849, form the basis of this Paper.

Richmond is very favourably circumstanced for drainage, being situated on elevated ground, mostly of a light, or gravelly character, and therefore, naturally dry and salubrious, but owing to the general and long-continued custom of draining the houses into cesspools, the ground had become so saturated with the filtration from them, as

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

not only to affect the purity of water in the wells, but even sometimes to occasion offensive exhalations from the surface.

In September 1849, the Author received orders from the Commissioners "to prepare a plan for the drainage of the town by means of tubular stoneware pipe sewers." Here a question came under consideration, as to the admission of surface and storm waters into pipe sewers; and seeing, that to make them capable of accommodating all the storm waters was quite impracticable, and knowing their liability to be choked up with the road drift, the Author decided to dispose of the surface waters by other channels. So the pipe sewers were designed, and their several sizes calculated for house drainage only. Finding, however, that there were in most of the streets, brick drains, which had, from time to time, been constructed for draining the roadways, they were retained for carrying away the surface and storm waters into the Thames.

This is probably the largest area on which the separate system has yet been carried into effect, in connexion with the Metropolis, and it involves a principle of some importance, in relation to town drainage, upon which different opinions are held by high authorities. The chief points in the arguments on either side are to the effect, that the combined system¹ is more favourable to economy in works of drainage, while on the other hand, the separate system facilitates the conversion of the sewage into manure, and its application to the purposes of agriculture, from its being more constant in quantity and less diluted, at times, by storm water.

In designing the sizes of the several sewers, consideration was given to the greatest number of houses likely ever to be erected, in addition to those already in existence upon the area to be drained, which comprised about 320 acres. An average was assumed of five persons to each house, and a water supply of 5 cubic feet of water per diem, to each individual; and it was calculated, that about half of the entire quantity of water used, would be discharged into the sewers, between the hours of 7 and 12 (A.M.) each day.

The natural declivity of the ground gave to the new sewers generally, a good fall; for instance, the sewer in Hill street and George street, composed of pipes of 9, 12½, 16, 18, and 20 inches diameter, —altogether 3,608 feet in length,—has a fall of 83½ feet. That in the Vineyard, with pipes of 10 and 12½ inches diameter, 2,007 feet in length, has 55½ feet of fall; that in Dunstable-shot, with pipes of 12½, 14, and 18 inches diameter, 2,829 feet long, has 20 feet of

¹ By combined system is here meant the combination of house drainage, with that for surface and storm waters.

fall; that in Park road, with 1,950 feet of pipes of 9 and 12½ inches diameter, has 45 feet of fall; and that in the Queen's road, 4,456 feet in length, with pipes of 10, 12½, 14, and 15 inches diameter, has a fall of 95 feet. The lowest gradient was 1 in 231, the greater number ranging between 1 in 120 and 1 in 44; and care was taken to avoid sudden changes in the gradients and to make that of each sewer as uniform as possible. The general depths of the sewers were such as to admit of a gradient of at least 1 in 60, in all the house drains.

The plans, when completed, comprised 52,876 feet of pipe sewers, varying in size from 9 inches to 20 inches in diameter, and 13,460 feet of brick sewers, part of which were to be 3 feet 9 inches by 2 feet 6 inches, and part 4 feet by 2 feet 9 inches, constituting, in fact, the main and outfall sewers for which pipes were considered inadequate.

In April 1850, the plans were, by order of the Commissioners, examined and revised by their Engineer-in-chief Mr. Frank Forster, and with some trifling alterations were, upon his recommendation, ordered to be carried into execution, at an estimated cost of £13,904.

In the month of September following, the main sewers, in that part of the town situate south of the railway, were contracted for; those on the north side of the line, together with the principal main sewer, being deferred for a time.

Whilst these sewers were in course of construction, junctions were put in, for connecting the branch sewers and the house drains; and to avoid the necessity of again breaking up the streets, for connecting the house drains with the sewers, these drains were extended to the kerb of the pavement, on each side of the street, and so branched as to make each junction serve for two, or three house drains.

These junctions were formed at an acute angle with the sewer, one, or two straight pipes being placed next to it, followed by curved pipes, to bring the branch into the line of the house drains; and wherever the house drains were not immediately connected, the ends of the branch pipes were stopped up with a piece of board fitted to the socket, to prevent anything from getting into them, and the gradients were so arranged, in the first 6 feet of the branch drains, next to the junction, that its invert should be, at that distance from the junction, on a level with the upper side of the pipes in the main sewer. This was done, in order to prevent the water from backing far up the house drains.

In the construction of pipe sewers, it is important, that the proper

position for all the house drains be previously ascertained, so that the junctions and branches for their reception may be properly placed; and they ought to be marked, so as to be readily found when wanted, and to avoid mistakes in opening the ground at wrong places.

A great part of the pipes for the main sewers, being of unusual sizes, with sockets somewhat longer than usual, were made to order, and no pipes were allowed to be used, until they had been inspected and approved; all distorted, cracked, or otherwise unsound pipes being rejected. On being laid, the joints of the pipes were rammed first, with well-tempered clay, to one-third the depth of the socket, above which the joint was made good with cement, the sockets being purposely made somewhat longer than usual; and great care was taken to pack the earth solidly about the pipes, so as to support them laterally, against the crushing pressure of the superincumbent earth. This is a very important part of the work, in constructing pipe sewers, particularly in closely timbered trenches, where in drawing out the timbers, a void, or vacancy is apt to be left alongside the pipes, which renders them more liable to be crushed by the weight above them.

In cutting the trenches, various qualities of ground were met with; in some parts there was a solid clay, in others a sharp dry sand, in others a sand charged with water, and in some places a slippery clay, intersected by numerous veins of sand, full of water. In part of Hill street the sewer was laid 19 feet under the surface, from 4 to 7 feet of the bottom of the trench being in a sharp running sand, charged with water, and at about 200 feet farther up the hill, the trench was cut through the solid blue London clay.

The estimated cost of the works comprised in this contract was £2,872 17s., and the entire cost of the work when completed, including all extras, was £2,665 17s. being about 7 per cent. within the estimate.

Shortly after their completion, the sewers were washed out by a flush of water sent through them, and the velocity of the flow in each was ascertained and found to agree very nearly with, being somewhat above, what the Author had calculated upon: the greatest being 3·81 feet and the least 1·88 feet per second.

In the construction of the house drains all the inlet pipes were trapped, and being of a size somewhat smaller than the succeeding pipes in the drain, whatever passed through the inlet was enabled to proceed freely onwards. No case of obstruction, or stoppage has yet taken place in either the sewers, or the house drains.¹

¹ Since this Paper was written, obstructions have taken place in the sewers, owing to the admission of surface waters, for which they were not adapted.

In some cases, where several adjoining premises belonged to one proprietor, combined house drainage was adopted, but generally, the several owners objected to that system, as exposing all the houses to every annoyance arising from any obstruction in, or interference with, any portion of such drains.

The several sizes of pipes, adopted for these works, were selected with a view to the introduction, into practice, of a series of sizes better adapted for drainage purposes, than those hitherto in use. For as hydraulic calculations are usually made in cubic feet, so pipes in a series of sizes, whose sectional areas represent decimal parts of a cubic foot, would be preferable; with this view, the Author submits the following seven sizes, believing they would be found sufficient for every purpose and be convenient in practice.

Diameter of pipes . . }	4 $\frac{1}{2}$	6 $\frac{1}{2}$	8 $\frac{1}{2}$	10 $\frac{1}{2}$	12 $\frac{1}{2}$	13 $\frac{1}{2}$	14 $\frac{7}{8}$	Inches.
Areas . .	$\frac{1}{100}$	$\frac{2}{100}$	$\frac{3}{100}$	$\frac{5}{100}$	$\frac{7}{100}$	$\frac{8.33}{100}$	$\frac{10}{100}$	Of a cubic foot.
Thickness of substance }	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	1 $\cdot$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	1 $\frac{1}{2}$	Inches.

As a general rule, the thickness of substance should not be less than one-tenth of the diameter of the pipe.

Pipes of a larger size than the above, are neither safe nor economical.¹

The consideration of this subject naturally led the Author into that of town drainage generally, and though on that topic, there are many conflicting opinions, still open to discussion among Engineers, yet he ventures to hope, that the following remarks, the result of his experience and of a careful consideration of the subject, may not be thought out of place.

If there is any portion of the works in the building of towns, which more than another ought to be imperishable, it is the sewers. Permanent efficiency is the first point to be attended to in their construction,—economy, the next; and with regard to this, the cost of their maintenance should be kept in view, as well as that of their construction in the first instance.

Stoneware pipes may be used for house drains and also for small sewers, in courts and alleys, and in some cases, for short street sewers, where new junctions for house drains are not likely to become

¹ See Advertisement of the Metropolitan Commissioners of Sewers in the 'Builder' of 21 May, 1853, relative to the size and substance of pipes.

necessary. The frequent breaking open of a pipe sewer, for the purpose of connecting additional house drains, very soon occasions its entire destruction, and the constant lifting of the pavement, for such purposes, is a cause of much of the annoyance and expense complained of in the use of pipe sewers. Every common sewer in the streets ought to be of a sufficient size to permit workmen to enter them without difficulty, or danger, whenever it may be necessary to connect additional house drains, or to make any repairs; and this should be done without creating any considerable obstruction within the sewers, or being under the necessity of breaking up the surface of the streets. In the reiterated statements advocating the exclusive use of pipe sewers, their sectional area has been treated entirely as a hydraulic question, and the conveyance and discharge of so much water as their only use and duty.

The proper and most economical sizes for sewers is, however, by no means a merely hydraulic question, though the conveyance of water may be their primary use. As regards economy in their construction, it may be observed, that a pipe sewer of 18 inches, or 24 inches diameter, is more expensive than a brick sewer of similar dimensions, and that the cost of sewers does not increase in proportion to their sectional areas, but as their circumferences. For instance, a circular sewer of 3 feet 6 inches diameter, has a sectional area of $9\frac{1}{4}$ feet, its circumference being 11 feet, while one of 4 feet diameter has an area of $12\frac{1}{4}$ feet, its circumference being also $12\frac{1}{4}$ feet; the difference in sectional area between the two sewers being 3 feet, while their difference in brickwork is only $1\frac{1}{4}$ foot. Again, the difference between a sewer of 4 feet and one of 6 feet diameter is 15 feet of area, for 6 feet of brickwork, and in a circular sewer of 4 feet diameter, there is one foot of brickwork for each foot of sectional area; while in a sewer of 8 feet diameter, there is only half a foot of brickwork for each foot of sectional area and the difference in the cost of excavation is still less. It appears very desirable to prevent, as much as possible, the road drift from entering the sewers, and this might, to a great extent, be effected by the construction of catch-pits of sufficient dimensions, at the gullies; they might be in the shape of a trough, say 6, or 9 feet in length, about 2 feet in width, and 4, or 6 feet deep, placed alongside the kerbstone, under the channel, or gutter, with suitable grates and cast-iron, or stone covers. The sand, &c. would be much more easily removed from these, than from the sewers, and with less offence, as it would be free from any unpleasant feculent matter; and in the absence of such road drift within the sewers, they may be more efficiently cleared by flushing them with water.

With regard to the flushing of sewers, it ought to be borne in mind, that the heavier matters held in suspension in the sewage, or driven along the sewers by the force of its current, never moves with the same velocity as the water, and consequently, with intermittent currents as in house drains, it is often left dry and sometimes becomes indurated, so that it cannot be moved by the succeeding flow of water; hence the necessity of a continuous current of water in all pipe sewers, to prevent the accumulation of matter within them. The sizes of all house drains and pipe sewers should be such, that they should never be more than four-fifths filled with water, or sewage, so as to allow of a free circulation of air through them, at all times, as the air not only facilitates the flowing of the water and promotes ventilation, but it also prevents the accumulation of highly-concentrated gases and their rising through the drains into the houses.

The paper is illustrated by a plan of the sewers of Richmond.

Mr. DONALDSON said, that at present, the drainage was conducted into the Thames, the main and outfall sewers not being yet completed, but it was intended to connect them, ultimately, with the Kennington sewer. The largest pipes he had employed, were 20 inches in diameter, but pipes of that size were rarely made so perfect as those of smaller dimensions, and there was great difficulty in well securing the joints. Where a larger diameter than 18 inches was required, he should prefer, on the score of safety, to construct a brick culvert, of which the cost would be about the same: the Contractors, indeed, finding at the time, some difficulty in obtaining the 20-inch pipes, offered to construct instead, a 30-inch sewer of bricks in cement. If pipe sewers could be made large enough to carry off the surface waters, and strong enough to bear the pressure of the superincumbent earth at great depths, he should prefer them to brick drains, provided the cost were the same; for the damage to drains arose not only from the wear and tear, but also from the rats, who could not attack the pipes, which should be carefully jointed with clay, not with cement. The use of pipes was, however, subject to this inconvenience, that whenever it became necessary to make a new junction, it was difficult to avoid breaking them in opening the ground, and thus a greater expense was often incurred, than would have resulted from the use of brick drains.

Mr. HERTSLET said, the most striking feature of the plan was the employment of the separate system. There was no doubt, that

sewers were originally intended to carry off the land and storm waters only, and up to the commencement of the present century, no one was permitted to use them for house drainage; but on the introduction of water-closets, permission was given by the Commissioners to connect them with the sewers. The consequence was, that the silt from the streets, mixing with the house drainage, caused a deposit, which could not be got rid of, except by continual flushing, in itself a clumsy expedient. He was in favour of separating the house drainage from the surface drainage, and so allowing what was artificially introduced, to be separately carried away; and he was glad to see that plan had been commenced at Richmond. Having thus a constant quantity of water to deal with, (after it had washed out a given number of houses), a manure of ascertainable value would be produced, not interfered with by the varying storms.

Mr. THOROLD observed, that in some cottages he had recently built, he had used separate drains for the storm waters and for the sewerage. He was of opinion, that it was preferable to carry off the surface water in open channels, than to allow it to mix with the house drainage.

Mr. HAYWOOD said, that this was the most extensive scale on which the system of separating the sullage from the pluvial waters, had ever yet been tried, and it was directly contrary to the experience of the last two hundred years. He should hesitate before intrusting the drainage of fifteen hundred houses to a pipe of 21 inches diameter, for whatever precautions might be taken, a great amount of solid matter would get into the sewers, and he much doubted whether this system would, ultimately, be found to be the most economical. He was decidedly of opinion, that all main sewers should be constructed of sufficient magnitude to allow of their being entered for the purposes of examination and of labour, and they should, therefore, be at least 4 feet high and 2 feet 6 inches wide, even if the immediate wants of the neighbourhood did not require such large dimensions, for in a very few years, their real economy would be demonstrated. He had tried back drainage, and it had certainly, in some cases, answered, but in others, in spite of the continual supervision of a man expressly employed for that purpose, and notwithstanding an ample supply of water at the head of each sewer, and a good fall, stoppages had occurred at least once a-year.

He would observe, in conclusion, that the drainage of Richmond presented a fair opportunity for testing the value of the employment of the sewage-manure, instead of turning it into the Thames.

Mr. DONALDSON remarked, that it had been his original intention to collect the sewage for that purpose, but he was compelled to relinquish the idea, because if it had been carried into effect, the funds would have proved inadequate to the full completion of the works.

Mr. BAZALGETTE considered Richmond most favourably situated for pipe drainage. A system of brick sewers existed there, sufficient for carrying off the storm waters; the levels of the town were remarkably good, and as the pipes had been carefully selected, and well laid, there was every probability, that they would answer in that town better than in most others. But it should be remembered, that when breakages, or stoppages took place in pipe sewers, the expense of repairs, or removing the stoppages, was tantamount to the re-construction of that portion of the sewer, an operation which always interrupted the traffic along the roads, or streets; whereas larger brick sewers were not liable to breakage, they could, from time to time, be repaired, if necessary, from the inside, without inconvenience to the traffic, and no stoppages could take place in such sewers. Again; the average cost of removing a stoppage from a house drain connected with a pipe sewer, would be from £3 to £4, whereas if the drains were connected with a large brick sewer, one labourer could, by entering the main sewers, examine and relieve the outlets of a dozen house drains in a single day. The first cost of a sewer, therefore, was not the only thing to be considered, for the accidents and injury to trade, consequent upon the obstruction of the traffic, frequently caused a saving in the first cost, to prove, eventually, an unwise economy. He was not an advocate for the general adoption of combined drainage in large cities. There were many instances where it might be advantageously employed, such as in poor and suburban property, with open gardens before and behind the houses; but in business streets, and amidst crowded London houses, combined drainage was frequently attended with the most serious inconvenience, and became a source of litigation and a positive injury to the health of the inhabitants of houses so connected. He considered, that the universal advocacy of any general rules in drainage matters had been, and must continue to be, attended with evil results. The experienced Engineer would adapt the means to the requirements of each individual case, and a beneficial result could only be obtained, by the unprejudiced application of different systems of drainage, to the localities where experience had shown them to be advantageous, rather than by the blind and exclusive advocacy of one system for every variety of circumstances.

Mr. HOSKING considered, that pipes were wholly unfit for main sewers, and he had hoped, that they would be no longer used. Substantial brick-built structures could alone, in his opinion, be safely depended on. He thought it essential, moreover, to any system, that the sewers should be ventilated in such manner, that the impure air generated in them, should be drawn up by shafts, and thrown off above the tops of the houses, so as to be dissipated with the smoke and other products of combustion, ejected from the chimney flues.

Mr. HAWKSLEY said, that although pipes might be exceedingly valuable for house drainage, they were of comparatively little use in street drainage, except in those instances where the streets had a great declivity, and there was, consequently, no danger of the sewers being stopped up. In the course of his practice, he had found it desirable, when sewers were required at a greater depth than 10 feet, to construct them large enough to admit workmen, instead of limiting them to the small theoretical dimensions, just sufficient to carry off the calculated amount of water. This system obviated the necessity for opening the ground, which was always, and especially when the depth was great, a source of great inconvenience to the neighbourhood. He also thought, that pipe sewers exceeding 15 inches in diameter, were not so convenient as brick drains, nor indeed so economical in point of first cost; and the latter had the additional advantages of giving less trouble in effecting junctions, and of being available for the purpose of getting dry foundations. He had heard of the supposed excellence of these water-tight pipes, when required to be carried through sand-beds, but he was of opinion, that drains in that position, should, on the contrary, be made so as to allow water to filter into them. The ordinary brick drains, which could be constructed in a variety of forms and applied in any way which circumstances might require, were more convenient, and of more practical application than pipe drains, in the different cases to which he had alluded. Brick sewers possessed greater strength and durability, and when exposed to a great pressure of superincumbent earth, they were evidently better than pipe drains which, if broken, caused great expense and inconvenience.

Mention had been made of the utility of pipe drains as a protection against rats, and of the great facilities they offered for making the work tight; but if a brick drain was well built, no rat could get through it, and with regard to jointing, which it had been said, should be done in clay, unless the clay was kept constantly moist, the upper part would crack and the gases would be emitted.

He thought a better material than earthenware could be used for house drains; he had, in some cases, employed iron pipes, and, except in respect of first cost, he believed they would be found to be the most advantageous.

Back drainage was a subject of great importance, and in a few towns where there happened to be mews at the backs of the houses, it was very convenient to employ that system; but in all other cases, back drainage laboured under the disadvantage of rendering the convenience of one person a source of inconvenience to others, and it generally occasioned much dissatisfaction. In spite of constant streams of water through small pipe drains, it was not possible to keep them free from accumulations caused by grease, hair, and other extraneous matters.

He saw no advantage in separating the sewage from the storm waters, as there appeared to be little expectation of sewage matter, as a liquid, ever being made extensively applicable for agricultural purposes. He had paid great attention to the subject, and he had found, that in provincial towns, where the inhabitants averaged five persons per house, the sullage water from each house was sufficient, even in dry weather, to satisfy one acre of land; there was, therefore, little prospect in towns containing ten thousand inhabitants, of ever making the sewage water available. It was also necessary to take into consideration, the great number of pipes and extent of privileges, which the distribution of the sewage would demand, privileges which could not, by any possibility, be of a permanent nature, for no enactment could compel the farmer to use and pay for the water in perpetuity. There were also many difficulties of a purely agricultural nature: in a dry season, every one would want the water at almost the same moment, and it was impossible to construct works of sufficient magnitude to transmit it; whilst in wet weather, and when the crops were ripening, it would not be wanted at all. For these reasons, he believed, that sewage water never would be extensively used for agricultural purposes, in this country, and therefore, that it was unnecessary, in laying out any drainage system, to provide for such a contingency. The valuable matter it held in solution, or suspension, could only be rendered available for manure by extracting it in a solid form, and it was more than doubtful whether its fertilizing powers were sufficiently great, to induce its sale at a price sufficient to cover the cost of production and carriage.

Certain experiments had been recently made by the Board of Health, for the purpose, as it would appear, of undermining all existing science in reference to the transmission of water through

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sewers. Not only had he found great discrepancies between the results stated and those obtained from the best-known formulæ, but they were, actually, not in accordance with each other, when due regard was had to all the minute circumstances which every well-informed experimentalist would take into account. In one of these experiments made with a 3-inch pipe, they reported, that a very large delivery, much exceeding that which any of the received formulæ would give, had been ascertained to take place. For greater accuracy, he had repeated the experiment, with two cisterns of equal capacity, and the result was, that whereas the formula gave a result of 375 lbs. of water, passing through the 3-inch pipe in a minute, the actual discharge was 374 lbs., a difference of only $\frac{1}{4}$, or $\frac{1}{4}$ per cent., whilst the experiments of the Board of Health differed to the extent of, at least, 50 per cent. The formula he had used, was the following:—

$$V = .77 \sqrt{\frac{h d}{l + 2\frac{1}{2} d}}$$

V , being the velocity, in yards per second,— l , the length of the pipe, in yards,— h and d , the head and diameter, both in inches. He laid little claim to this formula, although independently derived, as it did not greatly differ from those discovered by the best experimentalists, both in France and England. Its application to sewers of any description was of great importance, inasmuch as they must be made of sufficient capacity to carry off the storm water. This was, necessarily, an uncertain quantity, but it had been fixed in the blue-books at a preposterously small amount. In the great storm in London, in August 1846, $3\frac{3}{4}$ inches fell in two hours and twenty minutes, and at Nottingham, he had known 1.16 inch to fall in less than half-an-hour; yet the blue-books gave $\frac{1}{2}$, or $\frac{1}{4}$ an inch, as the quantity which would have to be conveyed away in twenty-four hours. Many mistakes had arisen, from sufficient attention not having been paid to the different circumstances, under which water was carried off by sewers. When water fell on slated roofs and flagged surfaces, it made its escape into the sewers almost immediately, and under these circumstances, the drains must be made large enough to convey not less than 2 inches of rain in an hour. But if the area over which the water fell, was considerable, it would be some time before it entered the head of the sewer, and still longer before the water would arrive at the bottom, the time varying, of course, with the extent of that area. The rules promulgated by the General Board of Health were perfectly fallacious, and if small pipe sewers were constructed on the principles laid down in the

blue-books, the consequence would be, that on the occasion of any wide-spread storm, the water would not be able to escape with sufficient rapidity, and the whole of the lower parts of London would be flooded.

A mistake had also been made by the General Board of Health, with regard to the friction of water passing through pipes of different materials. It was a well-ascertained fact, that the amount of friction did not depend on the relative smoothness of the surfaces, but on other conditions essentially different; for in an iron pipe, rough from the sand, it was sensibly the same as in a drawn lead pipe; and in a well-laid brick sewer, provided there were no projecting bricks, which would have an obstructing effect, the friction was no greater than in a glazed pipe, and the discharge was, practically, the same in both.

Mr. LESLIE said, there could be no doubt, that the experiments instituted by the Metropolitan Sewers Commission, had completely failed. With respect to back drainage, the great difficulties consisted in its interference with private property, in the refusal of the owners to allow the ground to be opened, and in the stoppage at a single junction, injuriously affecting all the drainage above that point. The Commission should only attend to drains carried through the public thoroughfares. He thought that it was not possible to use the sewage water, economically, for agricultural purposes, except under very peculiar circumstances.

Mr. SIMPSON, V.P., remarked, that he had laid down iron pipe drains, at intervals, during the last thirty years, and he had never found them to have sustained any serious injury from the sewage.

Mr. LAVERS said, that although pipes might be well adapted for house drains, he entertained great doubts as to their suitability, or economy for sewers, even under the favourable conditions presented at Richmond; circumstances, might, indeed, allow of their being so used, but he would make brick sewers the rule, and pipes the exception.

With respect to the area of pipes, he was decidedly of opinion, that they had been used of far too small a size, for both sewers and drains. The constant, indeed daily occurrence, of stoppages, not unfrequently involving expenses equal to the original cost, was a serious matter for consideration. These stoppages were generally to be attributed to the insufficient capacity of the pipes, and he thought, that their diameter should never be less than 6 inches for house drains and 12 inches for sewers. No surface waters should be allowed to enter, as road drift, straw, and other substances carried with them, would inevitably choke up the pipes; but if separate

sewers were to be provided for the surface waters, there could be no economy in using the pipe system. He strongly objected to sewers being constructed for one purpose only, as they never could be made generally available, and in his opinion, the area of a sewer should be sufficiently large to carry off, if required, the soil, the surface and the storm waters. Neglect of this precaution had, in a case which came under his notice, led to connecting an old brick barrel drain of 5 inches in diameter, with a pipe sewer of only 9 inches diameter.

The question of gradient appeared, in many cases, to have been thought unworthy of consideration; but the Author of the Paper had evidently paid great attention to this point, and if such gradients as those of which he had been able to avail himself, could be always secured, pipe sewers might be used with success.

Mr. HAYWOOD would mention one fact strongly corroborative of the advantages attending capacious brick sewers. Although in the city of London, twelve thousand houses drained into the sewers, yet there were not, annually, twenty stoppages which required the breaking up of the public streets. The causes of obstruction were, when they occurred beneath public ways, generally, easily detected by passing up the main sewers, and were remedied at an average expense of not more than a few shillings each. For house drains he preferred pipes up to 12 inches diameter, as the work could not be made smooth inside, when the brick drains were small. Within the last three years, eighteen hundred pipe drains had been laid down within the city of London.

Mr. R. STEPHENSON, M.P., V.P., said, that being one of the Commissioners of Sewers, he felt the greater interest in this important subject, which involved so many questions of detail. He hoped, that those Engineers to whom the sewerage of large towns was intrusted, would carefully record the practical results of their experience, and the various difficulties which might arise. He did not attach much importance to the different forms, whether elliptical, or circular, which might be given to sewers, but the relative advantages of pipe and brick drains and the proper sizes to be employed, were questions deserving the most mature consideration.

Mr. DONALDSON said, he was directed to prepare a scheme for the drainage of Richmond by means of tubular pipe sewers: the size and sort of sewers, therefore, were not altogether a matter of choice. Seeing that several of the sewers must be of a considerable length, it was his duty to provide against obstructions, and he had, consequently, allowed the road surface water to pass through the existing road drains into the river, in order to avoid the risk of the

sewers being choked up by the road drift. With larger main sewers which could be cleaned out, the admission of the surface water would have been less objectionable. As to the question of separate, or united drainage, he would not insist on the entire exclusion of all surface, or rain water, but he regarded it as unquestionably wrong, to combine the common brooks, or water-courses with the sewers. For house drains and for short branch sewers, he preferred pipes to brick drains, but all main sewers in principal streets should be of such a size, as to allow of the passage of workmen for the purposes of examination and repair, without difficulty, or danger to life.

It had been argued with some degree of plausibility, that a general system of sewers was somewhat analogous to the pipes for water supply, but though there might be an apparent resemblance between the systems, the one was quite the reverse of the other. The water-supply pipes having one well-guarded inlet, admitting pure water only, with, perhaps, ten thousand outlets, the chances of obstruction might be taken as 1 to 10,000; whilst the sewers had ten thousand inlets, admitting not only impure water holding matter in solution and in suspension, but other substances also, which must be pushed, or rolled through the pipes by the mechanical force of the current, and which, if once stopped, could not again be put in motion; the chances of obstruction in the sewers were, therefore, 10,000 to 1. With a good fall and a constant current of water, pipe sewers might be kept clear by frequent flushings; but unless the current were constant, so as to prevent the deposit from becoming indurated, occasional flushings would be of no use. Wherever such sewers were of any great length, small catch-pits and side entrances should be constructed, at suitable intervals, to collect and remove any solid substances that might get into them, by which means, the chances of obstruction would be materially diminished.

Mr. RENDEL,—President,—said, that the discussion had shown the great difference between mere theoretical speculations, and actual practical experience. In all questions of sewerage, Engineers must deal with towns as they found them, and not according to pre-conceived opinions, which did not always find their application.

April 6, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

The following candidates were balloted for, and duly elected :—
Price Prichard Baly, Thomas Drane, and Joseph Gibbs, as Members; Frederick Barry, Benjamin Baylis, Robert Daglish, jun., Captain Mark Huish, Thomas Hutchings, Thomas Marr Johnson, Charles William Lancaster, Henry John Marten, George Plucknett, and Braithwaite Poole, as Associates.

The discussion upon the Paper No. 869, "On the Drainage of Richmond, &c.," by Mr. G. DONALDSON, being renewed, was extended to such a length, as to preclude the reading of any other communication.

April 13, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 854. "Account of a Swing Bridge, over the River Rother, at Rye, on the line of the Ashford and Hastings branch of the South Eastern Railway." By CHARLES MAY, M. Inst. C.E.

THIS bridge was constructed by Messrs. Ransomes and May, of Ipswich, from the designs of Mr. P. W. Barlow, (M. Inst. C. E.,) the Engineer of the line, and although similar in principle to others previously erected in various parts of the country, it presents a few novel features, the description of which may probably be acceptable to the Institution. The chief points of difference between this and other swing bridges, are the arrangement of the tie-bars, and the details of some of the parts. The centre part of the bridge is carried by a pier, formed of thirty-seven wooden piles, each 14 inches square and 36 feet long, with the exception of the centre one, which is 16½ inches square and 39 feet long. The monkey, or ram, used for driving the piles, weighed 15 cwt., and had a fall of 15 feet. The maximum number of blows required to force down a pile, was one hundred and fifty, and the minimum, ninety-eight; the average being about one hundred and twenty-eight. In the first four blows, the average effect of each blow was 3 inches, but in some few instances, the effect was as much as 6 inches. During the last four blows, the descent of the pile varied from 3-8ths to 1-8th of an inch. The average depth to which the piles are driven, is 13 feet 9 inches. The piles are so arranged as to form a square of 22 feet, and are

strongly braced together and secured at the corners, by wrought-iron knees; the whole being surmounted with two layers of planking, each 6 inches thick, forming the foundation on which the bed, or lower roller path of the bridge immediately rests. In the stream, above and below the centre pier, are fender piles, arranged in the usual semi-elliptical form, so that when the bridge is swung open, the ends are immediately over them. The centre piece, on which the whole weight of the bridge rests, is a cast-iron ring with eight arms, weighing 13 tons, and of the ordinary girder form in section, except that the upper surface of the top web is slightly inclined outwards, and is turned so as to form a path for the conical rollers. The ring is composed of two pieces of cast-iron, connected down the centre of one line of arms by a rebated joint, planed, and fastened together by screw bolts $1\frac{1}{2}$ inch in diameter. There are sixteen conical rollers, each weighing $5\frac{1}{2}$ cwt., arranged at equal distances round a circle, 15 feet 6 inches in diameter, in such a manner, that any one of them can be taken out, without disturbing the others; they are retained in their positions, by a cast-iron frame, or live ring, weighing $4\frac{1}{2}$ tons, with eight radial arms; this is carried and held in its horizontal position by four of the rollers, the axes of which take a bearing underneath this frame, and so support the weight; the axes of the other rollers take a bearing sideways only, and merely assist in carrying the frame forward, without bearing any of the weight. These rollers are 1 foot 6 inches in diameter in the centre, and 1 foot wide on the bearing face; they are cast in iron moulds, but are only sufficiently chilled to give them a very close grain, without making them so hard as to prevent their being turned. On these rollers the top roller path is placed, the underside of the ring being inclined, and the two castings of which it is composed, being joined in the centre of one of the lines of arms, precisely in the same manner as the bottom roller path. On the top of this casting there are projections, with strong ribs underneath, for receiving and supporting the girders, and in the centre, there is a wrought-iron pin 6 inches in diameter, firmly secured to the boss of the ring, by means of a cotter passing through both. This pin passes also down through the centre of the live-roller-ring and the lower roller path, and serves effectually to preserve the concentricity of the whole.

The girders are 112 feet long, each weighing 24 tons, and are made up in four lengths, one joint being in the centre, and the others respectively half way between the centre and the ends. The joint in the centre is formed by vertical flanges, which are planed and secured together by means of bolts. The joints intermediate between the

centre and the ends, are similarly planed and bolted, but have in addition, a dowel, 4 inches square, placed as near as possible to the bottom of the girder; this dowel is drawn up by means of cotters passing through the ends of the girders. In the centre of the bridge, the girders are 3 feet 6 inches deep, gradually tapering to 2 feet 6 inches at the ends. The intermediate joints are covered by false pieces, bearing the initial letters of the Company, in a wreathed form, on a shield. The inner bottom flange of the girders is $8\frac{1}{2}$ inches wide, with brackets cast on it, at intervals of 3 feet, for receiving the cross timbers. At the ends of the bridge, the longitudinal girders are secured together by a cross girder, which passes underneath, and forms a bed for the main girders to rest on; the under surface of this cross girder is planed and slightly inclined, and rests on another girder secured to the land pier, the upper surface of which is also planed and inclined. The planed surfaces of these girders are in contact throughout their entire length; and the object of their surfaces being inclined, is to insure a perfect bearing for the ends, by allowing them to be slightly lifted, when the platform is swung home to its place. On the underside of the main girders, provision is made, at three places on each side of the centre of the bridge, for receiving the tie-bars, which are double and of flat iron, forming long links. At right angles to each line of tie-bar there are raised surfaces, on which are placed three blocks of cast-iron, each with a hole bored to receive a pin $2\frac{1}{2}$ inches in diameter. These blocks are arranged with spaces between them, sufficiently wide to admit the eyes on the end of the tie-bar, the eyes being also bored to receive the pin, which passes through the cast-iron blocks and the ends of the tie-bars, and then on to the other girder, making a corresponding connexion with it. On the first erection of the bridge, one thickness of the tie-bars, which are each 4 inches by 1 inch in section, and riveted together at intervals, with distance pieces, was placed on the inner side of the girders; but the Government Inspecting Officer of Railways, thinking that this arrangement rendered the roadway inconveniently narrow, it was altered, and the tie-bars were placed entirely outside the girders.

In the centre of the bridge and directly over the joint in the girders, the side standards, or A frames are placed, each weighing about 8 tons; they are connected together by a cast-iron arch, under which the roadway passes. Previous to the alteration of the situation of the tie-bars, the side standards were placed entirely on the main girders, and in a line with them; but to procure the increased width, it was found requisite to make them project over,

and they are now partly supported by a supplementary girder, made and planed exactly to the depth of the main girder, placed alongside and secured to it. By this means, advantage is still taken of the weight of the standards at the junction of the ends of the main girders, to hold them down.

There are three tie-bars on each side of the centre frame, taking hold of the girder at three points, nearly equidistant, and all tending to one point over the middle. Each tie-bar is adjustable for tension, by a right and left-handed screw, 3 inches in diameter and $\frac{1}{2}$ inch pitch; the nut of one end of the screw being in the tie-bar, and the nut of the other end, between two plates of wrought-iron, each 1 inch in thickness. These plates have distance pieces, and the nuts are carried by trunnions projecting through the plates; and a centre pin, 6 inches in diameter, passing through the plates and resting on a strong saddle, carries the whole. A weight of 112 lbs. on the end of a spanner 7 feet long, acting upon the screw of the outer tie-bar, was sufficient to elevate the end of the bridge. The whole of the upper connexion of tie-bars is concealed by ornamental mouldings, and is roofed over by cast-iron framing, filled in with plate-iron. In the centre of the roof, provision is made for a signal lamp, arranged so that it can be turned from below.

The turning of the bridge is effected by means of spur gearing, worked from a platform projecting from the face of each girder. Two men can, with ease, open the bridge in two minutes. When it is swung home, the bridge is retained in position by means of catches of the ordinary form, which can be secured by padlocks. The total weight of the moving part of the bridge is about 130 tons (of metal), to which is to be added the weight of the roadway.

The Paper is illustrated by one drawing, No. 4574.

Mr. BIDDER said, that he had already given his views on this subject, in the account of the Norwich and Reedham Bridges.* He laid no claim to originality in the application of the turn-table principle to bridges; he had only carried it out on a large scale, as all Engineers who were engaged on works of magnitude had opportunities of doing. He did not think the introduction of three tie-bars in the present case, an improvement; in the Norwich Bridge, which had two spans of 45 feet each, one tie-bar only was used over the A frame. The end of the girder deflected $\frac{3}{4}$ of an inch,

* Vide Minutes of Proceedings Inst. C. E. 1846, vol. v. p. 434, and 1847, vol. vi. p. 157.

which he did not consider to be objectionable; if the bed-plate was set with reference to this deflection, the girder would be brought level by the impinging load. At Reedham, he experienced great difficulties in the foundations, owing to the nature of the soil, and he had already described the plan to which he had recourse on that occasion; but in general, he admitted, that roller frames worked with the greatest facility. Mr. R. Stephenson had recently had to consider the principle on which swing bridges should be constructed for the railway across the Nile, and he had come to the conclusion, that the roller system was much preferable to the hydraulic principle of support.

Mr. C. MAY thought, that on the contrary, there were some practical advantages in adopting the system of three tie-bars. He would also point out an important fact, which could not fail to be useful in practice. It was not generally known, that by casting the rollers in an iron mould, it was possible to obtain a smooth surface, without at all impairing the hardness of the material. There was a class of pig-iron, that would not chill in an iron mould; the greater part of the Scotch irons had this property: a perfectly solid mass could thus be obtained, which on being turned, would not present a single speck on the surface. He might mention, as an instance of the facilities now afforded for working metals, that the main rings of the turn-table were jointed and planed by means of a machine, with as great ease as if they had been of wood.

Mr. P. W. BARLOW, through the SECRETARY, said, that the success of the Rye Bridge was rather due to the excellent workmanship, than to any novelty in the design, which was derived from Mr. Bidder's first bridge of the kind. The principal variations from it, consisted in the use of timber piles instead of cast-iron, and in avoiding the employment of the upright pillar.

No. 857. "Description of the Viaduct erected over the River Nore, near Thomastown, in the County of Kilkenny, to carry the Waterford and Kilkenny Railway." By Captain WILLIAM SCARTH MOORSOM, M. Inst. C. E.

THE Waterford and Kilkenny Railway Company was incorporated by Act of Parliament in the year 1845, at which time the Author was occasionally consulted by the Company; and upon his taking a more active charge of the works, in the spring of 1846, he found, that it was proposed to deviate from the limits of the line, autho-

rized by Parliament, so as to approach nearer to the village of Thomastown, and to erect a viaduct, consisting of several laminated timber arches, upon stone piers and abutments, similar to those previously built by Mr. Green, (M. Inst. C.E.,) in the neighbourhood of Newcastle-upon-Tyne.¹ The structure was to consist of seven arches, each of 180 feet span, and the total height, above the river, was to be about 70 feet. The first points to be considered, were the propriety of deviating from the authorized line of railway, and of erecting a viaduct of the particular character described. To test these points, specifications were prepared for contracts to embrace two alternative lines of railway, forming a loop in the neighbourhood of Thomastown; one line of the loop being that authorized by the Act, and the other, the proposed deviation. The tenders were found to be less expensive, by several thousand pounds, for the construction of the authorized line, and as neither presented any peculiar engineering superiority over the other, the authorized line was adopted, and the proposed deviation was abandoned.

The tenders sent in, had also embraced two designs for crossing the river and valley, with viaducts of equal extent, the masonry being alike for both designs; but in one design, the arch was proposed to be formed of laminated timber ribs, and in the other plan, a latticed beam of timber was proposed, the clear span in both cases being 200 feet. The tenders sent in for the execution of these designs, showed a difference of cost of about twenty per cent. in favour of the lattice design, as compared with the laminated arch; thus confirming the anticipations expressed in the Engineer's estimates, which had been previously laid before the Board of Directors.

The reason for adopting 200 feet as the span of the arch, was chiefly in order to avoid all question with the Board of Works, in Ireland. The works previously constructed on the Waterford and Kilkenny Railway had been subjected, under the provisions of the general consolidated Act of Parliament for railways, to the scrutiny of the Board of Works, in every instance where drainage was, in the remotest degree, likely to be affected; and the consequence had already been, that delays, very prejudicial to the finances of the Company, had occurred, before any approval was given by that Board, for commencing each work. In one instance, where a small arch of 12 feet span, was to be formed over a stream, with a

¹ Vide "Account of the Arched Timber Viaducts on the Newcastle and North Shields Railway, &c." Minutes of Proceedings Inst. C.E., 1841, vol. i., p. 88, and 1846, vol. v., p. 219.

bottom of firm limestone rock, the Board of Works required the Railway Company to excavate this rock 6 feet below the bed of the stream, and to put in foundations of masonry to that depth, instead of placing the foundations on the rock, at the existing level of the rocky bed. Considerations arising from these interruptions, induced the Author to lay before the Board of Works, such a design for crossing the River Nore, as should take away all possible ground of objection, on the score of interference with the river-way, and for carrying out such a design, a span of at least 200 feet, was necessary. This design also afforded the advantage of working in the foundations on dry ground, without the necessity of having coffer-dams, the piers on each side being so far from the river bed, that ordinary hand-pumps sufficed to keep down the water, which rose through the gravelly strata of the bed of the valley. This bed was found to consist of about 8 feet of gravelly loam, and about 3 feet of strong gravel resting, at depths varying from 9 to 11 feet, on the regular limestone beds of the district. The river, in its ordinary state, was about 9 feet deep in mid-channel, but being subject to floods, the rise of water was, at one time during the construction of the viaduct, as much as 7 feet, giving a total depth of 16 feet of water in mid-channel, and flowing over the entire valley for a breadth of 180 yards.

At the end of April 1846, tenders were sent in for the execution of a portion of the railway, adjoining to both sides of, and including the viaduct: the mean of the amounts quoted in these tenders, for the viaduct alone, was £8,104 11s. 6d. The tender of Messrs. Hammond and Murray, of Dublin, was accepted in May, and a contract having been made with them in the month of June, the foundations were got in during the latter part of August and the early part of September, in a favourable season. The masonry was subsequently executed by the same Contractors, nearly up to the level of the springing of the cross arches, when the finances of the Company not being adequate to meet the rapid demands of the workmen, and Messrs. Hammond and Murray having finished the other portions of their contract, they retired from the ground, by amicable arrangement, and the work was subsequently completed by smaller contracts, let in separate portions, during part of which only, the Author superintended its execution.

Owing to these interruptions, it is difficult to give any correct statistical account of the operations, which might serve as a guide for the future, in similar cases of construction. The labour employed on the masonry of the works, varied at different times during the progress of the works, from 199 labourers, 43 masons, 65 stone-cutters, and

15 horses, down to 15 labourers, 3 masons, 5 stone-cutters, and 1 horse. About 20 carpenters, 20 labourers, and 2 foremen were employed upon the timber work. In ninety working days, (exclusive of Sundays,) during which the works were carried on continuously, there were five holidays, peculiar to Ireland, and eleven other days, on which the work was interrupted either wholly, or partially, by storms, rain, or frost. If the progress of the work had been continued at the same rate at which it was carried on, while the funds of the Company were adequate, the masonry would have occupied nine months, and the whole structure would have had its respective parts fitted together in place, and completed for traffic in eleven months, dating from the laying of the first stone. The complaints of improper workmanship in the masonry were frequent, after the work had been re-let in smaller portions, and several feet in height of the upright work, and the whole of one of the cross arches on the south side of the river were pulled down, before the workmen could be persuaded to execute their task creditably. These instances are noticed, with the desire of impressing upon the younger Engineers who have daily charge of works, the necessity of being themselves on the spot at all hours, early and late, when the work is going on, as a defect is readily covered up and concealed from view in a few hours, and the result frequently becomes apparent, only when it is too late to prevent a disaster.

The stone, of which the masonry of this viaduct is built, was partly quarried on the spot intended for the foundations; but the upper courses of these foundations and all the masonry above ground, were quarried out of an adjoining cutting, on the line of railway, about half a mile north from the site of the building. The material is a compact stratified limestone, of dark-grey colour, forming a portion of the extensive beds, of which some varieties are well known, in England, under the name of Kilkenny marble.

The lime for mortar, above water level, was procured from kilns, about a mile distant, situated in quarries of the same stratification, but of a character somewhat more argillaceous; the lime used below the water level was hydraulic lias. The sand was found on the south side of the river, upon the line of railway, and was remarkably clean and sharp.

The specifications required, that the masonry should be built, as strong, best, 'coursed walling,' not inferior to the best samples, (pointed out by the Engineer,) in the bridges on the Great Southern and Western Railway, which had been already finished, and were near at hand for reference. The voussoirs were to be dressed on the beds, face, and joints, and to be laid so as to break bond

thoroughly well together, throughout each arch. The imposts and springing courses were always to be equal to the full thickness of the arch, and no stone used for such work, was to be less than 30 inches long. The joints of mortar were not to exceed one quarter of an inch for dressed stone-work, nor half an inch for the 'coursed walling,' and in the latter work, there was to be no difference between inside and outside work.

The timber for the arch, or beam, was specified to be of the best quality of Memel and Archangel fir. Some American pitch pine was introduced, (by the permission of the Engineer,) in the walings, but experience has shown, that it should be avoided in future. Every part of the timber, within view, was painted with four coats in white lead and oil, and was also specified to be subjected to Sir W. Burnett's process of saturating with chloride of zinc, but this part of the stipulation was subsequently modified.

As soon as the masonry had been carried up to the courses, necessary for receiving the iron and timber bands which steady the abutting pieces of the lattice beam, these bands were inserted in the masonry, and the construction of the beam itself was shortly afterwards commenced, on platforms placed on the shore of the river and covered with the flooring boards, which were afterwards taken up and used for the flooring of the bridge.

Full-sized drawings were made on these platforms, and by these drawings the lattice beams were carefully adjusted. Each piece was cut by a set of iron gauges; there was one set for cutting the 'halvings' of the lattice bars, and a second set for cutting the intersections of the lattice bars with the waling-pieces, and as the latter are all differently curved to each other, these gauges were made with the power of adjustment to various angles. There was also a set of 'wale-scarf' gauges, and another set for all the abutting joints of the cross framing, but these were ordinary gauges of sheet-iron. The bands, or waling-pieces were first cut to the proper dimensions, 15 inches by 7 inches each. The middle, fourth, and bottom bands were laid to a camber of 1 in 100. The top bands were of the same dimensions, but were not cambered. The bands were scarfed together the full length required; the scarfs of the respective bands being so placed as to divide the joints equally. The lattices, (which were of best Archangel deals, each $7\frac{1}{2}$ inches wide by $2\frac{1}{2}$ inches thick,) were then laid down on the bands, at the proper distances apart, and the exact size of the battens was marked on the bands, each in its true place. The bands were then cut to the depth of 2 inches, leaving the battens, when laid in place, to rise half an inch above the face of the band. The second layer of

lattice battens was then placed in the same way as the first, each being laid true to the proper angle, and each crossing of the battens with each other and with the bands, being truly marked. The crossings were then cut out, so that the battens, when driven close together, were reduced to a thickness of 4 inches. The second thickness of bands, or waling-pieces, was then laid in place, and cut in the same way as the first, and over these, the next thickness of battens was placed and cut out as before. When this was completed, the thickness of the entire rib, at the lines of the three bands, became 21 inches, and at the crossings of the battens, 8 inches. The rib was then taken to pieces and re-erected on the platforms before described. The joists to support the floor, were cut 2 feet longer than the width between the ribs, every fourth joist being 6 feet longer than its neighbours and resting on the band below it, in order to receive the ends of the struts from the uppermost bands. The joists were clipped to a depth of 1 inch over the bands on which they rested, so as to act as cross ties. Similar ties, 12 inches by 4½ inches, were carried across from each of the three lower bands. Longitudinal crown pieces, 9 inches by 6 inches, were placed directly under the centre of the uppermost joists; they were scarfed together so as to run the whole length of the bridge, and to brace and support the flooring. Diagonal cross struts, in two parallel pieces, each 9 inches by 3 inches, running from the crown piece to the lower waling, were bolted on each side of every alternate cross tie, so as to brace the whole of the cross framing strongly together. Diagonal struts, 6 inches by 4½ inches, were also carried longitudinally from every second cross tie, on the second tier, to the crown piece at every second cross tie, on the upper tier. The third and fourth tiers of cross ties were diagonally strutted with pieces, 6 inches by 4 inches, and bolted to uprights. The floor of each line of way was strutted with diagonals, 6 inches by 4½ inches, tenoned and strapped to the second tier of cross ties, and fitted into cast-iron sockets abutting against a crown piece, 9 inches by 6 inches, under each alternate top joist, at the centre of each line of way. The flooring was formed of planks 2 inches thick, laid diagonally and spiked to the joists. Cast-iron shoes were introduced at the butt-end of the struts; and wrought-iron straps secured the diagonal struts to the horizontal ties. Angle pieces of wrought-iron connected the ties with the uprights and bands.

The ends of the lattice frames were further stiffened by long wrought-iron straps, bolted to the bottom bearing beams, and carried to the uppermost waling-pieces, so as to bind the extreme bearings of each lattice beam firmly together, while at the same time, the

openings in the masonry of the abutments were designed to be left clear, for the beams to rest on their bearings, independent of the masonry above that level. This intention was not fulfilled in executing the work, the masonry having been erroneously banded in with the upper parts of the lattice beams. It had been designed, that the lattices should have been fastened by oak trenails, but large nails were substituted, at a time when the Engineer-in-Chief had no longer any control over the work.

A platform, about 40 feet in width, was laid on the top of the staging for fitting the lattice in place, at about 3 feet below the level of the lower wale-pieces. Uprights of half balk were fixed on this, vertically and fair in line for the outside of the wale-pieces, and stayed across the top and diagonally. To these uprights, cleats were spiked, in the lines of the curves of the lower sides of the several wale-pieces. The outside wale-pieces were first laid along these cleats and fixed, then one row of lattice bars was put in place, then another wale-piece, and so on until the whole was completed. Meanwhile, at every convenient point, cross braces were got in and bolted fast, so as to keep all steady.

The inertia of the mass of timber was so great, and the staying of the stage was so firm, that no inconvenient vibration was felt, during the execution of this part of the work, in spite of some heavy gales, which then occurred. The cross framing was all fitted and marked on a third set of platforms, and was rapidly brought up and put together, as soon as the lattice bars were ready to receive it.

All the intersections of every lattice bar were spiked with two large nails, for which the holes were previously bored. The waling-pieces were drawn close with bolts, and the joints were made water-tight. The diagonal flooring planks were then bolted and spiked down to the cross bearers, and the cleats on the uprights were knocked away. The arch, or lattice beam now rested on wedges purposely placed under the lower wales, when these were first adjusted. On the 1st of May, 1850, these wedges were removed, when the entire beam of 200 feet span subsided, in the course of the same afternoon, 3 inches in the centre, and on the following morning, the gauges showed a further subsidence of a quarter of an inch, so that the structure with its own weight only, appeared to repose with a total deflection of $3\frac{1}{4}$ inches. Between the 3rd and the 10th of May, several locomotive trains of various weights were passed over the arch, at speeds of from twenty to thirty miles per hour, until it was found, that a further deflection had taken place in the centre, of $1\frac{1}{2}$ inch: or in other words, that the deflection of the

arch, (without a load,) which on the 2nd of May, was $3\frac{1}{2}$ inches had become $5\frac{1}{2}$ inches on the 10th of May. The maximum load which had passed over, appears to have been an engine with its train of loaded waggons, estimated at 65 tons.

On the 12th of May, the Government Inspector tested the arch with various trains and loads, and amongst others, with two engines and a train of loaded waggons, nearly 200 feet in length, extending over the entire length of the arch, being about 146 tons weight upon it. The result of all these tests was, that with the heaviest train, passing at a speed of twenty-six miles per hour, the arch deflected in the centre $2\frac{1}{2}$ inches and rose again $1\frac{1}{2}$ inch, thus leaving a permanent deflection after the trials were concluded, of about $6\frac{1}{2}$ inches below the level of the centre line of cleats, on which the lines of the arch had been laid.

The regular traffic of the line has been constantly passing over the viaduct from that period to the present time, and up to the month of April, 1851, a further deflection has been observed of about three-quarters of an inch: this cannot be ascribed to any particular loads, that have passed over the bridge, nor to any settlement at the extremities, but to the gradual drying of the whole of the timber, after being so thoroughly exposed to the air, and for the greater part, secured from wet. Thus the total settlement in twelve months from the date of striking the supports, has been $7\frac{1}{2}$ inches. The Engineer's expectation of permanent settlement, after ordinary trains should have worked over the arch, was 9 inches; and the calculation of insistent weight which might be placed upon this beam, without fracture, was nearly 600 tons, if distributed over its surface.

The quantity of solid masonry in the work is 8,984 cubic yards. The timber is about 264 loads. The weight of cast-iron is nearly $4\frac{1}{2}$ tons, and of wrought-iron, about 12 tons; and the total cube of the work measured as one solid mass, from the bottom of the foundations to the top of the parapet, is 49,268 cubic yards. The width of the arch is 25 feet 3 inches in the clear between the parapets, and is designed for a double line of railway of 5 feet 3 inches gauge, but only a single line of way is, at present, laid down. The height of the rails above the ordinary water surface is 68 feet, and the extreme height from the foundations to the top of the parapet, is 84 feet. The extreme length from end to end of the parapet, is 428 feet.

The cost of the masonry was about £4,800, and of the arch about £3,800; thus the stonework of all kinds, averaged about ten shillings and eight-pence per cubic yard, and the arch, or beam, came to about

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£15 per foot of its length, the total length being 215 feet, including the portions which rest on the piers at each end of the beam. The cost of the whole mass, taken as a solid, averaged three shillings and three-pence halfpenny per cubic yard.

The Author has to express his sense of the skill and intelligence exhibited by Mr. Robert Mallet, (M. Inst. C. E.,) under contract with whose firm, the woodwork was constructed and erected, and has been maintained for twelve months after its completion. He suggested some judicious alterations of the original design, and he contributed to the details noticed in this Paper. The work is believed to be the largest beam both in span and in magnitude, executed in the United Kingdom, on the lattice principle, and Mr. Mallet conducted his portion of it, with a spirit to do justice to one of the greatest ornaments of his native country.

Mr. BIDDER thought, that it would have been both better and cheaper to have erected a tubular bridge. He was not an advocate of the system of lattice bridges, nor could he understand how the conclusion had been arrived at, that the deflection of so complex a structure as that described in the Paper, should be exactly 9 inches.

Mr. DOYNE had erected several large lattice bridges of 100 feet to 200 feet span, and he was convinced that, under certain circumstances, this system could be employed with greater advantage than any other principle of construction.

April 20, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 877. "Railway Accidents; their cause and means of prevention; detailing particularly the various contrivances which are in use, and have been proposed." By Captain MARK HUISE, Assoc. Inst. C. E.

In entering upon the subject of this Paper, it is unnecessary to occupy time, in demonstrating the fact, that compared with its results, whether as regards the ease and celerity of transit, or the facility of conveying numbers, railway travelling, even in its present state, is incomparably safer than any previously designed system of locomotion.

Contrasting the mere numbers transported from one locality to another, in the present day, by railways, with those conveyed by

coaches during their most active period, the ratio of safety is indubitably in favour of the former; while if the difference of speed is imported into the consideration, the value of the immunity from accident, in the case of railways, is considerably enhanced. Even at the present time, when railway travelling has superseded all other modes of inland communication, it is doubtful whether the contingencies attending conveyance by horses in this kingdom, embracing in that category the omnibus traffic, do not annually exceed in amount the casualties on railways, and it has even been asserted on apparently sufficient data, that the accidents to pedestrians in a given period, would still leave railway managers in a position to point with satisfaction to the superiority of their system, on the score of safety.¹

The attention which has latterly been paid to the statistics of railways, and the periodical publication of the Government returns, direct public attention very pointedly to the aggregate of accident, in a manner which has not been attempted in any other department, and tend to fix a degree of responsibility, and to cast an amount of odium, which have not attached to less prominent and perhaps less useful adaptations of science and discovery. Were the casualties to steam-boats as carefully chronicled, and the deaths in mining as elaborately tabulated, or were even the fact of a British vessel being wrecked on each tide throughout the year, as generally known, the public would view more justly the occurrence under the railway system, of those contingencies, which, even under the most perfect management, must ever accompany the arrangements of fallible man. While, however, it is pleaded in behalf of one of the greatest inventions of the nineteenth century, that due regard must be had to comparative results, and while it cannot be denied, that but little consideration has been exhibited, either by the public, or the press, and still less sympathy been shown, during the difficulties under which the railways of Great Britain have struggled into their present position, it is not contended, either that the system has yet attained the degree of perfection and consequent safety of which it is susceptible, or that it has, in all cases, been administered in the most judicious manner.

Experience is daily adding to the knowledge of the dangers which, in an infinite variety of occult forms, necessarily attach to the momentum of high speeds, and this experience is constantly suggesting fresh precautions and means of prevention. To detail as briefly

¹ Seven accidents to persons crossing thoroughfares in London, were recently reported in the same newspaper.

as possible some of the prominent causes of accident, and to explain the measures adopted for securing the safety of the public, (the paramount and primary duty of railway management,) is the subject of the present Paper.

Without further preliminary remark, therefore, the first point of interest is the road, and the contingencies connected with it, embracing the very important subject of the permanent way.

A firm, substantial, and well-kept road, is undoubtedly the basis of all safety in railway travelling, and with the heavy and increasing traffic now passing over the iron highways of Great Britain, it requires the most incessant vigilance, (especially since the speed of the trains has been increased,) to maintain the way in the condition which is essential for the safety of the passengers and the economy of the rolling stock. As the intervals between trains become less frequent, as the speed of travelling is accelerated, and as the heavy merchandise traffic, which promises to form, ere long, the most important feature in the receipts of many lines, increases, the repairs become greater, and at the same time, more difficult to carry on. It is not intended in these brief remarks, to enter on the very extensive field of 'permanent way,' especially as it is a subject so familiar to all civil Engineers, but the experience of the Author leads him to the conclusion, that even more attention than has hitherto been given to this fundamental question, must be devoted to it in future, or the theories which have been constructed, and the practice based upon them, will be found to fail. Improvements are continually introduced, for the purpose of obtaining a sound continuous road, and there is no doubt, that the recognized evils will eventually point out their own remedy. Fishing the rails is now a popular and, as far as partial experience can determine, an efficient mode of strengthening a railway, for the increased traffic it has to bear. Other measures, having the same object in view, are in course of experiment, and stone blocks are generally being rejected in favour of wooden sleepers. Heavier rails, with shorter bearings, are gradually being introduced, wherever relaying has become necessary; and engineers are fully sensible, that a road constructed to support moderate trains, drawn by light engines at low speeds, is utterly inadequate to endure the crushing effects of monster locomotives at express speeds. The defects of lamination, deflection, and spitting of the rails are rapidly increasing, whilst transverse fractures, (a species of failure almost unknown a few years ago,) are now of frequent occurrence; and the difficulty of maintaining the gauge of the line, under the present weights, not only increases, but much of the oscillating motion which is so unpleasant to the traveller, and so destructive to the

stock employed, must be attributed to the same cause. Requiring, as railways do, superior rails to bear the increased strain now thrown upon them, it is painful to observe, that instead of keeping pace with the necessities of the case, the rail-makers have allowed their production to deteriorate very greatly; indeed, the utmost caution is now required in the purchase of rails; with every security afforded by name and standing in the trade, the greatest disappointments are daily arising, and the result promises to be very serious, unless instant measures are adopted, by the principal makers, to retrieve their characters in this respect. Many of the rails, recently supplied, have shown symptoms of failure at an unusually early period, and are, in many instances, in a worse condition, after two, or three years' wear, than old and much lighter rails, which have been subjected to precisely the same duty, for twelve to sixteen years. So grave has the aspect of this matter become, and so general has been the complaint, that one railway company has come to the determination of rolling its own rails, and has given instructions for erecting works for the purpose. Under all the disadvantages, however, to which allusion has been made, it is, after all, remarkable how very few accidents have arisen from a defective state of the road itself. The circumstance of a train running off the line is very rare; and when such an event does occur, it may generally be attributed to some palpable neglect of the plate-layers, to some defect in the machinery, or to some obstructions designedly placed on the line. The latter is unhappily a very fertile source of danger, and one against which, where a morbid desire to inflict injury guides the miscreant hand, it is very-difficult indeed to guard. It is little known how frequent, how ingenious, and how varied these attempts have become; and although from the vigilance exercised, and from fortunate and providential causes, the real damage effected has been far less than could have been supposed, it is lamentable to think, that in addition to the ordinary risks of rapid locomotion, it should be necessary to guard continually against so diabolical a mode of wreaking a petty vengeance, or of gratifying a mischievous disposition. Numerous instances might be given, which would excite surprise, from the cunning design exhibited, and the care apparently exercised in selecting a spot likely to be fraught with the greatest amount of mischief; but the detail would occupy too much space. One only, and that the latest attempt of this kind, may be mentioned:—A few weeks ago, upon a branch line in Lancashire, the points of an important siding were jammed open: and in order to prevent the signal-man from averting the intended accident, the wire of the auxiliary signal was lashed with a piece of string, and was thus pre-

vented from acting. Happily, however, by a fortuitous circumstance, the villainy was discovered a few minutes before the passenger train approached. It has been customary, when such attempts have been made, to offer a considerable reward for the discovery of the perpetrators. It is questionable, however, whether setting a patient watch, and establishing a careful inquiry throughout the neighbourhood, are not more effectual means of tracing the culprits. Considerable success has certainly attended this course, while there is, it is believed, no instance of a voluntary statement for the purpose of securing the reward. The punishment for this class of offences has recently been made more severe; and although it is not to be expected that they should altogether cease, it is hoped that they may become less frequent.

The alternations of weather, in a climate so variable as England, have a material influence on the permanent way, and on any great and sudden change, either to heavy rain, after lengthened drought; or to a rapid thaw, after continued frost, increased watchfulness is necessary on the part of the upholders of the road, and the engine-drivers and guards. It is at such periods, that the weak points in a road show themselves; a sudden relaxation of the line seems at once to take place, and unless counteracted by vigilant attention, great danger must result.

The rapid development of general traffic on all the main arterial lines in the kingdom, and the transfer to them of much of the heavy trade which was formerly carried on by canals, have caused a very great extension of siding accommodation, and this by multiplying the points and crossings in the main line, has *pro tanto* increased the risk attending them. Anything which breaks the continuity of the rails is necessarily an evil, and tends in a certain degree to develop danger; and as these frequent 'turns out' cannot be avoided on a line of heavy traffic, the railway manager is compelled to rely on regulations and signals, and to that extent is obliged to incur the additional hazard which attends the employment of officials, from whose neglect, or want of discretion, the most fatal consequences may at any moment arise. On the London and North Western Railway, the increase of sidings, during the last few years, amounts to 53 miles. In laying down these sidings one very fertile source of danger has, however, been considerably reduced. 'Facing points' were formerly common and numerous: they are now rarer; and although at the junctions of branches, and in some peculiar positions, they cannot be altogether abolished, no railway manager will rest contented, while one of these points is allowed, unnecessarily, to remain upon his line.

In connection with this subject, allusion may be made to self-acting switches. Useful as this invention has proved, it has been attended with concomitant evils of no trifling magnitude, and many accidents have occurred from a reliance on them. They require constant vigilance to secure their being kept clean and well oiled, and it is very difficult to insure proper attention being always paid to them. It may indeed be remarked as a general rule, that so far from machinery being a means of safety, (when used for superseding personal inspection and manipulation,) it is usually a source of increased danger, and the numerous clever contrivances and complicated arrangements which are so continually submitted to the examination and opinion of railway men, though evidencing the ingenuity and industry of the projectors, are generally valueless as practical means of operation. The greatest simplicity in everything connected with the road, and the signals upon it, will provide the nearest approach to security, and in proportion as such simplicity is departed from, it is probable that a practical good will be sacrificed, in endeavouring to attain a theoretic excellence. In concluding this branch of the subject, it may be repeated, that fewer accidents to life and property arise from the road, than from any other cause, and were casualties confined to those attributable to 'the way,' the annals of railway accidents would be scanty in the extreme.

The next question of interest is the 'locomotive,' that extraordinary invention, which has already changed and ameliorated the whole surface of society, and which is destined to work still greater revolutions in the social fabric of the world. The increased power and capacity, the more perfect finish of the various working parts of the engine, and the general improvements in form and proportions, which have been gradually introduced, have rendered far less frequent than heretofore, those delays and irregularities which are always attended with inconvenience, if not with danger; yet it would be too much to expect immunity from casualties to so elaborate and so severely-tested a machine; and though the parts have been greatly strengthened in every respect, the improvement does not appear to more than meet the greater demands on its powers, in consequence of the increased loads and speeds which are now adopted.

The variety of mishaps to which a locomotive is liable, will be seen from the following table, containing the causes of one thousand failures on the London and North Western Railway. This return spreads over a lengthened period, comprises every description of defect, and is given for the purpose of proportion only.

ANALYSIS of 1,000 cases of ENGINE FAILURES and DEFECTS, occurring on the
LONDON and NORTH-WESTERN and subsidiary RAILWAYS.

Stock of Engines, 587.

157	Burst and leaky tubes.	904	Total brought forward.
92	Broken springs.	7	Broken blow-off and other cocks
89	Broken valve-spindles.	6	Broken quadrant-studs.
77	Broken and defective pumps.	6	Lost and loose regulator spin-
48	Broken feed-pipes.		dles.
40	Broken piston-rods and pistons.	6	Broken gibs.
34	Broken and damaged valves	5	Broken stay in fire-boxes.
	and valvular apparatus.	5	Detached ash-pans.
34	Lost and broken bolts and pins	3	Smoke-box and chimney-end
	(various).		on fire.
34	Fire-bars burnt out.	3	Broken brackets of weigh-bar
31	Lost and-broken cotters (va-		shafts.
	rious).	3	Feed-pipes stopped up, dropped
29	Plugs and joints blown out.		fire.
25	Broken and lost eccentric-	3	Broken spring-balances.
	straps.	3	Broken slide-blocks.
21	Broken wheels and tyres.	3	Broken crank-rods.
21	Broken and bent coupling and	3	Tubes drawn in chimney-end.
	connecting rods.	3	Broken axle-boxes.
17	Broken sponge-boxes.	3	Broken slide-valves.
17	Broken and bent eccentric-	3	Broken right-hand bearings.
	rods.	3	Broken glands.
17	Broken crank-pins.	3	Defective hose-pipes.
15	Broken and shifted eccentric-	3	Broken piston-rings.
	sheafs.	2	Broken breaks.
15	Broken coupling and draw bars.	2	Lost quadrant-washers.
13	Broken crank and other axles.	2	Broken goss-head spindles.
13	Broken eccentric straps and	2	Mud-hole doors defective.
	bolts.	2	Broken weigh-bar shafts.
13	Broken and damaged steam	2	Broken brasses of driving jour-
	and suction pipes.		nals.
13	Broken and defective reversing-	2	Broken studs of link-motion.
	levers.	2	Broken catches of fire-bars.
11	Broken connecting-rod straps.	2	Broken glass tubes.
11	Broken middle-bearings.	1	Nut off tender draw-bar.
9	Broken spring-bearings, screws,	1	Broken tender eye-bolt.
	and buckles.	1	Defective whistle.
8	Broken lifting-links.	1	Boiler burst.
904	Total carried forward.	1000	Gross Total.

It would be interesting to know how far this return coincides with the results on other railways, because, were somewhat similar ratios evolved, the knowledge of the proportions would direct the special attention of locomotive superintendents, to the necessity of guarding more particularly against casualties of most frequent occurrence. It will be observed, that burst and leaky tubes nearly double any other class of failure, and that these, with broken springs and broken valves, amount to one-third of the entire number. Very few, indeed, of the above failures are attended with any direct danger to the

public, but as producing a temporary, or permanent inability of the engine to carry on its train, they may be the remote cause of collision.

The carriage stock of railway companies is, generally, of so superior a kind, both as to design and construction, that accidents arising from its failure are very rare. The wheels and axle-boxes are the most severely tested parts of the vehicle; but if originally of a proper construction, give very little trouble in their maintenance and repair. Experience seems to give the superiority to the wooden wheels, of which there are many kinds in use. A spring sometimes breaks, and a tyre occasionally fails, in which case the wheel is in danger of flying to pieces; but the instances are so infrequent, that they are not sources of much anxiety to a railway manager. Defective workmanship, where either the carriage, or the principal parts of it, are supplied by contract, has specially to be guarded against; where these are sound and the carriage is daily examined, it may be relied on for a very long period. During the last four years only six wheels have failed, in the very large stock of the London and North Western Company. The heating of axles, however, is a source of frequent annoyance and alarm to passengers. Since the bearings were increased in size, and more care has been exercised to make the cover fit close, and to preserve the grease free from dust, when not in use, this cause of trouble has diminished, and the recent introduction of the patent axle-box, which, under proper management, will run many hundreds of miles without being fed, bids fair to obviate the evil to a considerable extent, if not to prevent it altogether; still, on a hot summer's day, in a district with sandy ballast, it is, and will always be, very difficult to keep the axles of a fast train cool. The couplings of carriages are seldom broken, even by sudden jerks.

There is, perhaps, no more alarming occurrence than a fire in a passenger train. Still, however, there has not been an instance in this country, of any loss of life from this cause, nor have the cases been numerous, but there have been several narrow escapes, and the accident is one to which a train may be at any instant subject from the escape of heated coke. Spontaneous combustion has also in more than one instance, nearly produced a serious conflagration. This has arisen from the incautious introduction of lucifer matches, or similar combustibles, among the luggage of the passengers. The occurrence of fire, and the feeling of insecurity which attaches to the passenger, from a feeling of inability to stop the train, if desired, from this or any other cause, are continually reproducing a multitude of schemes for communicating between the passenger and the guard,

and the guard and the driver. These have assumed a multiplicity of forms, yet the principle is generally identical, viz., a connection by wire, or rope, between the engine and the guard's van. Simple and inexpensive as this contrivance is, it fails in practice, and after being adopted more than once, has again been laid aside. The whole of the trains of a northern company were some time back fitted with the means, by a flexible jointed tube, of communicating with the driver, but it has not been considered a successful attempt to overcome the difficulty. The same may be said of the numerous contrivances for arresting the passage of a train, by the instantaneous application of a number of powerful breaks, (some of the inventions applying the break to the road itself); of the proposals to work signals by means of the engine striking certain levers as it passes; and hundreds of similar suggestions. Among the inventions transmitted to the Author, and for most of which compensation was claimed, one proposed to arrange a set of signals, which were to be successively struck down by the chimney of the engine; and another, in order to stop a train in the shortest space, gravely proposed, that a large anchor attached to a stout cable, should be thrown out of the stern! Perhaps the most feasible and favourite plan for giving confidence to passengers, has been to continue the foot boards of carriages, so as to form a continuous narrow platform, with a brass rod attached to the panel of the carriages; by this means, a passenger might escape and pass safely along to the guard's van, or to the engine. The plan was suggested to, and recommended by the Railway Commissioners. A committee of the most experienced railway officers was appointed by the Clearing-house to consider it. They have done so, and their report, founded on returns and reasonings, which appear unanswerable, is the unanimous condemnation of the measure. We are thus apparently as far off as ever, from gratifying the popular demand for instant communication between the passenger and the guard, and it is possible, that no better plan will be discovered, than that now in use on the London and North Western line. It is as follows:—The guard's van at the rear of the train, projects more than a foot beyond the carriage on either side. In this projection a glass window is fitted, the guard's covered seat being opposite to it. He is thus enabled to see the entire length of the train, and can scarcely fail to observe a hand, or a handkerchief, if waved from a window. This contrivance is, evidently, unavailing at night, unless a spare light were by some means placed at the disposal of the passenger. At present, therefore, it only to some extent meets an evil, for which no more practical and complete cure has yet been provided. The almost universal practice of leaving the doors at one side unlocked,

is a source of not infrequent accident; yet so distasteful in public opinion is a locked door, that only one Company has ventured to adopt it as a rule. The reckless conduct of many habitual travellers may yet possibly force it as a regulation on others, especially if juries continue to inflict severe punishment on Companies, even when the fault is primarily with the passenger himself.

If, however, there is no part of the railway machinery, from which so little danger may be apprehended as the passenger carriage, the same cannot be claimed on the part of the merchandise waggon. Whether the absence of direct danger to human life, or an injudicious economy has been the cause, the fact is, that in no portion of the system has so little improvement been exhibited, and in which, at the present moment, there is so great a necessity for a complete modification. In this respect, England is far behind the Continent. The axes of waggon stock have, in many instances, been of the most faulty model and material. The accidents to the trains, from the fracture of these parts, have been very numerous, while the destruction of property has been sufficient to have paid for a very superior vehicle. In one recent instance, several hundred axes, of a peculiar form, were removed from a leading railway, after a short experience of their working. Axes are now made much stronger than formerly; $3\frac{1}{2}$ inches used to be the ordinary diameter; 4 inches is now considered a minimum: and although more attention has been bestowed on the form and taper of the axle itself, still very much remains to be done in this matter. The fact of the crystallization of the iron by the repeated vibrations, and the peculiar causes of incipient fractures, are still debatable points with Engineers and waggon-builders. It is desirable, that by a thorough examination of the subject, these disputed questions should be disposed of. The wrought-iron wheels of merchandise waggons, do not on the whole give much trouble. The most defective part of the waggon is, however, the mode of coupling. This is of the rudest kind, and it is matter of surprise, that a vigorous and combined effort has not been made by the railway interest to improve it. Very few merchandise waggons have spring buffers, and even those that have them, are simply linked together by a loose chain. Every one must have noticed the bumping sound produced in the starting and stopping of a merchandise train. Even where the driver is very careful, the succession of heavy blows in a long train is sufficient to injure the stock, and to break any delicate articles that may be conveyed in the trucks; but when it becomes necessary to arrest a train suddenly, the shocks are very destructive to the frame-work. This evil, great as it is, is aggravated by the circumstance of a variety of waggons

being run in the same train; a light and short waggon is probably found between two long and heavy ones, and the irregularity of loading, according to the staple trade of a particular district, still further increases the risk. From the through system of traffic, the waggons of half-a-dozen companies may frequently be found in one train, and as these are not built to any particular height, or breadth, the ends do not strike evenly, and on receiving a check, a tendency to mount, (especially if the waggon is unevenly loaded, which must always be the case with some descriptions of goods,) is apparent. Covered vans, low timber trucks, and box-waggons, are all run together, in trains of from thirty to sixty vehicles, and at speeds varying from fifteen to twenty miles an hour. It is, in fact, a wonder that a traffic, so conducted, is not subject to continual accident; and the circumstance of the comparative freedom from casualty is rather an evidence of the extreme safety of transit over parallel iron bars, than any defence of a system which is no credit to the mechanical skill of the country. Until every waggon is coupled up to spring buffers, in the same manner as a passenger carriage, and until either by general concert, or by compulsory regulation, the standard central height, and central breadth between the buffers are matter of regulation, the risk of accident and the certainty of damage must continue. The Author succeeded, some years ago, in obtaining, through the medium of the Railway Board, a general concurrence on the subject of the buffers of passenger carriages; but no measures have yet been effectual, as regards merchandise vehicles.

Fires in merchandise trains are of frequent occurrence, and from the susceptibility of the tarpaulin covering to ignite, and the presence of straw in the loading, considerable danger must always exist. This fact, and the damage which fine goods receive from wet, have caused the introduction of covered waggons. The use of these waggons is now greatly increasing, and for all goods capable of being closely packed, they bid fair to entirely supersede the open truck and tarpaulin. The first cost is greater, but the repairs of the sheets will, in three, or four years, fully compensate for the difference.

Allusion has now been made to those points connected with the road, and the machinery employed upon it, from which loss of life and injury to person and property most generally arise. The whole of these causes, however, do not produce a tithe of the accidents which result from inattention to signals, and the neglect of regulations. Of all sources of danger on a railway, these are the most prolific. Human agency is necessarily imperfect, and it cannot be

expected, that the servants of a railway company, however carefully selected and diligently tutored, will be exempt from such a general law. The effects of a momentary forgetfulness, or an instant's neglect, are frequently fraught with tremendous consequences, and the miscalculation of a few yards may produce the most lamentable results. There is, therefore, no part of the system to which the railway manager looks with more anxiety, than to the efficiency of the signals on the line. If these are either defective, or too limited in number, the casualty which will probably result, must be attributed to the carelessness which has overlooked the danger, or to the injudicious economy which has permitted it. Railway stationary signals have within a few years been greatly improved. The introduction of the lofty semaphores has left little to be desired in this respect, while the further use of the auxiliary signal has completed this most necessary adjunct to safe working. The distance at which these signals should be planted, must depend on the nature of the ground, and the character of the gradient. Generally speaking, with the prevailing high speeds and heavy trains, the extended arm of an auxiliary signal should be seen at a distance of from 800 to 1500 yards. The space within which a train can be pulled up, varies very much according to the state of the weather, as well as the tenacity of the breaks, the speed, the inclination of the road, and the weight of the load; but for practical purposes, the distance named above will be found to answer, and less than this should not be accepted, where circumstances permit its being obtained. Not only is the positive safety of the train secured by such a signal, but the nerve and the steadiness of the engine-driver are supported by the feeling, that the means of protection are provided for him. Care should be taken to fix the signal, so that no distant objects may interfere with the free sight of it: and as the speed, weight, and number of trains on the line increase, opportunity should be taken periodically to revise the distances, to ascertain that every doubtful point is covered, and that nothing which may be provided against by caution, is left to contingency. Some difference has existed among railway managers, as to the mode of dealing with signals, at junctions with branch lines. It has, however, been generally ruled, that the safest course is to keep the danger, or stop signal fixed against the branch, so that no train may be allowed to enter on the main line, until such signal be removed. The safety of the trains moving between stations, and temporarily impeded, from any cause, depends on the attention paid by the guards to the regulation, to proceed back a certain distance with the hand signal. The distance varies from 500 to 800 yards, according to the rules of different companies. Probably the latter is too

far, unless the distance terminates in a curve, as a hand signal may be seen, under ordinary circumstances, from 300 to 500 yards further. Nothing is more difficult, however, than to secure strict obedience to this rule, and the most particular attention should attach to any breach of it. Upon it hinges the safety of the train, and the fact of no accident happening, should not be a bar to the most severe punishment of the offending party. A careful guard will also be guided by the state of the rails and the atmosphere; if the former are what is termed 'greasy,' or the latter is heavy, a longer distance than ordinary is evidently required to protect the train. Until recently, no special means existed, of securing a train against collision during a fog. The detonating signal supplied this deficiency, and has become one of the most useful protections which the railway manager possesses. Its use, therefore, is universal, as in a humid climate, like that of England, it was absolutely necessary to complete the code of signals. During a recent dense fog which lasted for two days, and was so thick as to render objects invisible at a distance of a very few yards, the London and North Western Railway was necessarily worked entirely by the detonating signals. The experiment was successful; and although irregularities were very frequent, no accident occurred, although nearly 400 trains ran during that anxious time.

Great weight is generally attached to the question of regularity in the times of the trains, as an essential element in their safety, and whenever an accident occurs, the press and public opinion, as expressed through a jury, seize on this point as the primary cause of the mishap. The Author would by no means undervalue the importance of punctuality, and as rigid an adherence, as possible, to the published time-tables; but it may be doubted whether undue stress has not been attached to it. Under a well-regulated system of signals, and with a well-disciplined staff, the greatest irregularity, whatever inconvenience it may produce, ought not to lead to danger. To a certain extent, the very uncertainty of the passage of trains produces safety, by the continual vigilance it necessitates, and as few accidents occur in the most frequented thoroughfare of London, so the most crowded parts of a railway exhibit the greatest freedom from casualty.

It is fortunate, indeed, that the public safety is not necessarily linked with punctuality, for the extension of the system, and the connection with cross lines, by coaches and steam-boats, is daily importing into the long trains fresh chances of delay. The mail train of the London and North Western Company starts from Dublin on the west, and Aberdeen on the north; during its passage it connects

with a great number of railways, the irregularities of each, and all of which become multiplied as the train advances. When, therefore, it reaches the London and North Western line, it has probably missed its appointed turn, it consequently becomes an exceptional train during its entire transit, yet none is better protected, or passes along the railway with greater safety. The facility of working a trunk railway, with a heavy traffic, under the variations alluded to, has, however, been greatly promoted by the introduction and extensive use of the electric telegraph. Just as the demands on the railway system were beginning to outgrow its existing machinery for safety, this remarkable power came to its aid, and extended its capacity in an incalculable degree. The effect cannot be better illustrated, than by a reference to its operation on the London and North Western Railway, during the Great Exhibition. Prior to the opening, the Directors had been much pressed by the Royal Commissioners, for greatly-reduced fares, to afford all classes of the community an opportunity of participating in an enjoyment, which could not be expected to recur. The result is well known. The most distant parts of the kingdom poured their population into London, and the aggregate number exceeded expectation. In addition to the passengers by the ordinary trains on that railway, which were very largely increased, 775,000 persons were conveyed to and from London by excursion trains, for whose conveyance 24,000 extra carriages passed through the Euston Station. The receipts of the railway rose to £70,000 in a single week. That such an extraordinary traffic, centering in a single focus, arriving at irregular hours, and in almost unlimited numbers from more than thirty railways, should have been carried on for six continuous months, without the most trifling casualty, or without interruption to the very extensive business in merchandise, coals, and cattle, continually moving on the line, and with a remarkable punctuality, (looking to the contingencies arising from the irregularities of neighbouring lines,) is due, not more to the discipline and good conduct of all the servants, than to the power of regulation, which a liberal use of the telegraph placed at their disposal. The Author, who had the charge of the whole arrangements, foresaw the impossibility of reliance being placed on ordinary measures, to govern so irregular a traffic. From the very great distance many of these trains had to traverse, before reaching the North Western Railway, dependent in many cases, also, on steam-boats, and the delay incident on overloaded trains, it was impossible to rely on any time bill, framed by the forwarding company, while the number of these excursion trains flowing from every quarter, and amounting sometimes to between

twenty and thirty a-day (many of them not known to be *en route* till they reached some one, or other of the termini of the line), rendered it impossible to fix any specific time for their transit. The attempt would have so clogged and impeded the service, as to have introduced the greatest irregularity into every department. Under these circumstances the following plan was adopted, and continued with success throughout the whole period of the Exhibition. The running speed of all excursion trains was fixed with reference to their weight, and a general rule in accordance was issued. Instant notice was given by telegraph, of the arrival at and the departure of each train from every terminus, and this information being re-transmitted to every important station, and repeated as the train passed in both directions, a time-bill was immediately constructed, according to the prescribed table of speeds, from which correct information was obtained and acted on, with promptness, and precision; and thus, instead of dependence being placed on theoretical time-bills, which in the majority of cases would have created difficulty and confusion, the telegraph, by tracing every train through its entire journey, became a practical instrument of safety of infinitely greater value. On every long line of railway the first-class stations are rarely more than twenty miles apart. It is evident, therefore, that by the establishment of telegraphic instruments at these distances, the railway becomes a system of detached and corrective links, and the irregularities inseparable from the system are modified and adjusted. Some years ago, a strong impression prevailed in high quarters, that the trunk line of the London and North Western Railway was overloaded with traffic, and relief lines were talked of as a consequent necessity. By the improvements since introduced, and by the assistance which science has thus placed at the disposal of that Company, the traffic has since been doubled in quantity, and there is at this moment a greater capacity for increasing it further, than at any previous period of its history. The value of the telegraph, for the working of tunnels, and the absolute protection from collision which is thus afforded, cannot be over-rated.

The length to which these remarks have extended, renders it necessary to be very brief in alluding to other and less important causes of accident.

Defective breaks and fractures of couplings on steep inclines, have not unfrequently led to accident; yet the working of the Lickey incline is evidence of the safety of the system, if only ordinary care and caution are exercised. More than one accident has arisen from trees falling across the rails. Care should, therefore, be taken to

remove all that are likely to be affected by storms, or by the slipping of the ground. Trains have occasionally been thrown off the rails by cattle jumping out in transit, and some very narrow escapes have occurred in consequence. Level crossings are also a fruitful source of danger if they are not very carefully watched. A sad catalogue of deaths, at these crossings, will be found in the Parliamentary Returns, and their increasing number indicates the necessity for greater vigilance, or a change of practice. Lastly, reference must be made to the tendency of Parliament, in recent sessions, to extend what are termed 'running powers.' It is to be greatly feared, that if this system is permitted to extend, a new element of the greatest danger will be introduced, the effect of which it is at present scarcely possible to calculate. If, with the whole energies of a concentrated establishment, under well-known rules and discipline, danger cannot be avoided, what must be expected from strange and rival executives using the same line of rails, and unacquainted with its peculiarities?

The regulations of most companies have now a very general similarity of principle, modified by the circumstances of each line. These rules are constantly undergoing improvement, and any fresh cause of danger is provided for, as it develops itself. Accidents, however, very rarely happen from foreseen circumstances. They are generally of a compound character, and result from the simultaneous conjunction of several causes. It is easy to be wise after the event; but so long as machinery is material, and human nature is fallible, it is to be feared, that although experience and skill may diminish, they will not prevent the recurrence of events that startle society, and cast blame on railway management. The rapid glance which has been thrown on the more salient points of danger, shows the variety of causes from which it may at any moment arise. The increasing nature of the transit, renders such casualties possible at any moment. In the year 1851, during which 7,900,000 passengers, (nearly one-third of the population of England,) travelled on the London and North Western Railway, only one individual met his death; yet this casualty, from which the Author also suffered, was the effect of the gravest disobedience of orders. The exception proves the rule, and it is due to the engine-drivers and guards of Great Britain, to state, that there is probably no class of men, to whom such serious duties are intrusted, and who repay with such fidelity, attention, and skill, the confidence reposed in them. Kind and considerate treatment, and good wages, combined with the utmost strictness of discipline,—a readiness to reward merit, and a rigid determination to punish severely any dereliction of duty, are

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the best means of forming good and attentive servants. Inebriety should never, under any circumstances, be overlooked, or pardoned, whatever claims the offender may otherwise possess in regard to general efficiency, or length of service. A system of regular promotion, wherever it can be applied, is perhaps the greatest stimulus to good conduct; and experience has clearly shown, that, in general, better results have been obtained by rewarding obedience, than by the greatest severity in punishing misconduct. The habits of order and regularity which are thus generated, extend beyond their immediate sphere, and react on society at large. As an instrument for advancing the social position of the country, the railway system, with all its admitted defects, exercises no light influence, and although the benefits are not unmixed with evil, the advantages are purchased at a less cost of personal suffering and sacrifice, than, (looking at the conditions under which they are obtained,) might reasonably be expected.

April 27, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 875. "The Economy of Railways as a means of transit, comprising the Classification of the Traffic, in relation to the most appropriate Speeds for the conveyance of Passengers and Merchandise." By BRAITHWAITE POOLE, Assoc. Inst. C.E.

ONE of the means by which a nation is rendered great and prosperous, is the cheap and rapid conveyance of its people, and their merchandise, from one place to another. Railways now constitute by far the most gigantic system of internal communication in this country, although their effects upon its agricultural, mineral, and manufacturing resources, are only just beginning to be developed and to be appreciated by the community.

¹ The discussion on this, in conjunction with the preceding Paper, was continued over portions of four evenings, but an abstract of the whole is given consecutively.

It would, perhaps, have been wise and much more economical, if the Government had, in the first instance, determined the directions in which railways should have been constructed throughout Great Britain and Ireland, instead of sanctioning the expenditure of such a large amount of extra capital, in making so many duplicate and unnecessarily competing lines; thereby causing traffic to be carried temporarily at ruinous fares and rates, until such limited opposition became consolidated, and ended in leasing, guaranteeing, or amalgamating the properties; in fact, present competition is now, in railway parlance, understood to mean eventual combination.

The directors and managers of railway companies generally assume, that their trains are arranged in such manner, as will command the largest amount of traffic, at the highest available rates, and the lowest cost of working, and the passenger traffic has thus been developed to an unparalleled extent; 85,391,095 persons, or nearly four times the population of Great Britain, having travelled by the railways of the United Kingdom during the year 1851.¹ Passengers are now conveyed in luxuriously-appointed carriages, at three times the speed, and one-third the fares formerly charged by the old stage, or mail coaches, (which averaged five pence per mile inside, and three pence per mile outside, for each passenger, exclusive of fees, or meals on the road,) and even less than the gratuity of three pence per mile, customarily given to every post-boy. In like manner, merchandise and minerals are now conveyed by railway companies, at less than half the ordinary rates charged by canal carriers fifteen years ago.

The economy, or saving to the community, by the formation of railways, is a national benefit, extending, in the aggregate, to an almost incalculable amount. In point of time, the public is enabled to transact as much business, and to see as much in one day, as their forefathers could perform, or see in a month. Troops are removed from one part of the country to another, with their baggage and ammunition, with amazing rapidity, and at about one-tenth of the expense formerly incurred. Tradesmen and artisans are enabled to live cheaper outside, than inside of large towns. The cost of fuel has been reduced 50 per cent. Manufactured goods are brought to market in much larger quantities, and the prices of the whole are proportionally reduced.

¹ *Vide Parliamentary Returns.*

The expense of the conveyance of merchandise, minerals, and agricultural produce, as compared with the rates charged by canals and turnpike roads fifteen years ago, is now reduced to the extent of £10,000,000 annually : the reductions, which are equal to 50 per cent. having been entirely effected through the superiority of railways over the other means of communication. The pecuniary saving to passengers, assuming the same number to have travelled by stage coaches, would annually exceed £8,000,000, and that to the Post-office for the conveyance of letters, &c., £9,000,000,—forming a total saving of £27,000,000 per annum ; an amount approaching the interest of the national debt, and exceeding the annual charge for the army, navy, ordnance, and miscellaneous expenditure of Great Britain.

These figures are the result of analytical statements of the total traffic of the United Kingdom, in merchandise, cattle, passengers, and parcels, by comparison of the rates charged and the quantities carried immediately before the establishment of railways, and those of the present day ; but to furnish all these Tables in detail, would be too extensive an undertaking for this brief essay.

The agriculturist, the landowner, and the farmer, save on an average, in the transport of manure and produce by railways, 10 shillings per acre. This has been proved by the parliamentary evidence of competent parties ; as also the fact, that owing to the facilities now afforded for conveying tiles and lime by railways, a great extent of inferior land has been cultivated in many places, especially in the Eastern Counties districts, and raised in annual value from 5 shillings to 30 shillings and 40 shillings an acre.

Landowners are now convinced of these advantages and offer inducements, instead of impediments, to the construction of new railways through their estates. Of this, the present position of the Deeside Railway is an example, Sir A. Burnett having agreed to give four miles of his land, over which the line will pass, at a rent of only £40 a year, and his neighbour, Mr. Kinloch, to give about two miles, for only £5 a year.

To elucidate the practical economy of railways, and their benefits to the farmer, the shareholder and the public, a recent instance may be noticed, where the produce of one of the finest fields of turnips in the kingdom, was carried to market a distance of fifteen miles by railway, at 2*s.* 6*d.* per ton, a charge far less than it would have cost to cart them along the turnpike road. Trains of returned wagons passed the field daily, and as fast as they were provided, the farmer loaded, and the consignees unloaded the

turnips; the farmer was thus enabled to dispose of his produce quicker than formerly, the public bought it cheaper, and the railway shareholders realized £230 nett.

The rates now charged for the carriage of live stock, by railway, are considerably less than the expense of driving by turnpike road, especially in the case of fat cattle, which sustain a loss on a drive of 60 to 70 miles, of at least 5 per cent. on their value, or equal to the whole expense of driving. But cattle traffic is, probably, the least remunerative of any on a railway, owing to the extremely low rates of carriage,—the great cost of making and working the wagons,—the rotting occasioned by the manure,—the infrequency of loading,—and the necessity of finding engine power to draw wagons which invariably return empty. The great secret of economy in working railways is to arrange so that the carriages and wagons may run full both ways, instead of empty one way, which is daily the case with far too many, upon every line in the kingdom: all fares and rates should be regulated, wherever practicable, to meet this important desideratum.

The economy which may be introduced into the system generally, must now be considered.

It would be an economy, if the whole of the railways in Great Britain were worked in four divisions, or amalgamations. Thus:—

1. The North Western.
2. The Great Northern.
3. The Great Western.
4. The South Eastern and Western.

The apportionment of territories might be arranged by the different companies, and in case of dispute, the disinterested divisions could arbitrate for the others.

If these four great railway companies were to reserve in their own hands the maintenance of way, under the direction of a competent Engineer, and work the lines themselves, instead of paying the cost and a profit also, to Contractors.

If such railway companies, in addition to engines, carriages and wagons, were to manufacture their own rails, chairs, and spikes, instead of using cheap and bad iron, such as has, hitherto, been frequently supplied.

If the whole of the rolling stock in the kingdom were amalgamated, and made common to all lines, each of the four divisions contributing to its maintenance, in proportion to its traffic, and having a certain number of engines, carriages and wagons appor-

tioned for local traffic. One central construction establishment might be formed, with auxiliary repairing shops in districts near junctions.

If, upon parallel lines, the trains were run alternately, or wherever practicable, upon one of the two lines only, thereby giving better accommodation to the public, increasing the traffic, and diminishing the working expenses.

If uniformity were observed in the construction of everything, from a carriage to a screw, *e. g.*—If wagons were built of an uniform height, and with spring buffers, not only for conveying goods of a brittle nature more safely, but especially for easing the incessant concussions when shunting and marshalling the trains, which rough usage unavoidably necessitates more extensive repairs in four, or five years upon the old style of wagon, than would suffice to pay for the extra cost of the spring buffers.

If all wagons intended for the conveyance of miscellaneous merchandise, were built with arched tops, and sliding doors to lock up, inasmuch as, when in motion, they offer far less resistance to the wind than sheeted wagons of the same height, and protect the goods much more securely against fire, wet, pilferage, or loss by falling off: besides which it must be remembered, that the sheets, or covers used upon an open wagon during twelve years, (the average time of its duration,) are equivalent to one-third of its cost. In fact, the expense attendant upon sheets, would suffice to pay for keeping the wagons in repair, under this improved system of management.

If the proprietors of minerals, such as coal, salt, lime, stone, &c., were all induced to provide wagons for their own traffic, as it is well known, that they can and will work their own wagons economically and return them quickly, but not those belonging to others.

If accommodation were provided for supplies of coke at certain stations and junctions, instead of using wagons as coke-sheds, which is the most expensive of all systems. The capital spent in employing upwards of 8,000 wagons to convey 750,000 tons of coke consumed annually on the railways, exceeds £500,000; whereas £50,000 would suffice to build sheds for two months supply, (125,000 tons,) and thus 6,000 wagons would be liberated, and transferred for service in the merchandise department.

If, in every instance, the lightest engines competent to draw the trains were employed; and if, instead of running long heavy trains of passengers and goods with heavy engines, such trains were divided, the consequent extraordinary wear and tear of the permanent way would be avoided.

If at the large stations, such as in London, Liverpool, Manchester, Birmingham, Bristol, Newcastle-upon-Tyne, &c., the railway companies were to manufacture gas for their own use, it would, in most cases, effect a saving of from 30 to 40 per cent. upon the present prices paid for it to the various gas companies; because the railway companies would have only a small amount of mains to provide for carrying the gas through their stations, whereas the gas companies have to charge interest upon the capital expended in mains distributed over a large number of streets, and to allow for the waste contingent upon such a vast quantity of pipes.

If all the extensive goods stations were worked by steam power, or water power, wherever practicable, instead of by horses, or manual labour; as the saving in time and in portorage by the quicker mode of operation, is very considerable.

If full-sized turntables, (13 feet in diameter,) in lieu of small ones, were laid down, where practicable, under cover, to avoid their being choked up with wet and dirt from exposure to the weather, by which extra expense in portorage is involved, as instead of two men, eight, or ten are required to turn the carriages and wagons.

If the exclusive use of two, or more wires of the telegraph were required by the railway companies, not only for the transmission of ordinary messages, but especially for ascertaining the exact position each morning, and at any time, or place, of the entire rolling stock of the country, in order to expedite its distribution, daily and hourly, as required.

Numerous points in economy, apparently of minor import, suggest themselves, which although they may be considered, *per se*, of little consequence, yet entail in the aggregate, a serious expenditure; such as polishing the domes of engines, instead of painting them over, a profuse use of stores, stationery, &c. in place of restricting the supplies.

The general classifications for passengers and merchandise are quintuple arrangements, reversed in either department; the 'First class' being the highest charge for passengers, and the lowest charge for goods. The following are the ordinary fares charged for

PASSENGERS.

By Express Class	.	2½d.	per mile.
„ First	„	2½	„
„ Second	„	1½	„
„ Third	„	1	„
„ Excursion	„	0½	„

The ordinary rates vary from 1*d.* to 6*d.* per ton per mile for

MERCHANDISE.

- 1st Class On raw materials, as grain, timber, &c.
 2nd „ groceries, hardware, earthenware, &c.
 3rd „ manufactured goods, cottons, woollens, &c.
 4th „ drugs, plated and light goods, &c.
 5th „ furniture, feathers, hats, &c.

GENERAL CLASSIFICATION OF GOODS BY MERCHANDISE TRAINS UPON ALL RAILWAYS, commencing 1st January, 1852.

MINERAL CLASS.—(Station to Station only.)

Being Loaded and Unloaded by OWNERS, and Conveyed at THEIR RISK in full Loads.

Bricks, <i>common</i>	Dross	Materials for Road	Sand
Cannel*	Fire Bricks	Repairs	Scoria
Clay	Flags	Manure, in bulk	Slates, <i>common</i>
Coal*	Granite, <i>undressed</i>	Peat	Slag
Compost	Iron Stone	Pyrites	Stone of all sorts
Chromate Ores	Iron Ore	Salt,* rock and un-	Tiles
Coke*	Iron, Pig and Scrap	manufactured	Turf
Culm	Lime & Lime Stone*		

* These articles are carried at Special Rates in Owners' Wagons.

When loaded in Company's Wagons, to be unloaded within Twenty four hours, or demurrage at the rate of 3*s.* per diem will be charged.

SPECIAL CLASS.—(Station to Station only.)

Carried in full Loads, if not less than One Ton, otherwise chargeable at FIRST-CLASS RATES.

Alabaster	Coal Dust, in bags	Iron Boiler Plates,	Pelts, wet
Asphaltum	and casks	Bar, and other un-	Pig Lead
Baggage, Military, 2 <i>d.</i>	Copper Ore	damageable iron	Plaster
per ton per mile	Corn	Iron Rails and Chairs	Postwood, <i>M. Wt.</i>
Barytes	Deals, 2½ Tons per	Iron Pipes	Potatoes, <i>old</i>
Baywood	Standard	Lathwood	Pozzolano
Beans, as grain	Emery Stone	Lead Ore	Propwood, <i>M. Wt.</i>
Bones, <i>common</i> , for	Farina	Linseed, in full loads	Retorts
size or manure	Flints	Linseed Meal	Salt Cake
Bran	Flour	Logwood	Sanitary Tubes
Burr Stones	Founders' Dust	Mahogany, in logs	Sleepers
Brimstone	Fuller's Earth	Malt and Meal	Soda Ash
Cabbages, loose	Fustic	Manganese	Soot, in bags
Carrots, loose	Gas and Water Pipes	Mangel Wurzel	Staves
Cement	Grain	Metal, <i>old</i>	Timber
Chalk	Guano and packed	Nitrate of Soda	Turnips
Charcoal	Manures	Ochre	Whiting
China Clay	Gypsum	Oil Cake	Vegetables, loose
Clog Blocks, rough	Hominy	Peas, as grain	

FIRST CLASS

Ale & Porter, in casks	Cables, iron	Felloes	Jute
Alum	Canada Plates	Flummery	Laths, in bundles
Anchors	Cannon	Girders, iron, not ex-	Lead Ashes, in bags
Anvils	Cannon Balls	ceeding 20 feet long	Lead, sheet and piping
Apples and Pears,	Castings, heavy	Galvanised Iron	Lead, red and white
common	Chains and Traces	Grease	Litharge
Argols	Chicory Root	Greaves	Marble, in blocks
Arm & Share Moulds	Clog Soles, dressed	Hoofs, in casks	Metals, sheathing, &c.
Ashes, Pot and Pearl	Coppers	Hides, raw, salted, or	Nails, iron
Barilla	Cotton Wool	in bales	Nicaragua Wood
Bark, Tanner's, Pkd.	Cresote, in casks	Hoops, wood and iron	Onions
Black Bottles	Crowbars	Horn tips, packed	Palm Oil
Blacking	Cullett	Ice, packed	Paper, coarse
Bleaching Powder	Dyewoods, not else-	Iron Tubing	Pegs
Blubber	where specified	Iron, Hoop, Sheet, or	Pitch
Bobbins	Earthenware Bottles	other damageable	Pumice Stone
Boilers, small, under	Empty Packages, full	Iron Turntables, in	Putty
four tons	loads	parts	Quercitron Bark

FIRST CLASS—continued.

Nags	Saltpetre	Spelter	Tin
Railway Pins, Wheels, Axles, and Springs	Seal Skins, <i>wet and salted</i>	Spikes	Vinegar
Rivets	Sheathing	Sugar, <i>raw</i>	Vitriol Stone
Ropes	Shot, <i>cannon</i>	Sulphate of Soda	Wire Rods and Wire, <i>not damageable</i>
Rosin	Size, <i>liquid</i>	Tallow	Woad
Rotten Stone	Soda	Tar	Zinc, <i>ingots, &c.</i>

SECOND CLASS.

Alkanet Root	Dregs	Lemon Juice	Shell Lac
Annatto	Drugs, <i>in casks</i>	Lignum Vite	Shot, <i>small, in bags</i>
Archil	Drysalteries, <i>in casks</i>	Linseed, <i>small lots</i>	Shovels
Arrow Root	Earthenware & China, <i>in casks and crates</i>	Lime Salt	Shudes
Assafetida	Edge Tools	Locks	Shumac
Bacon	Eggs, <i>in crates & boxes</i>	Locomotive Tubes	Silk Waste
Bagging	Emery	Machines, <i>Weighing, large</i>	Simovi
Balsam Copaiba	Felt	Machinery, <i>heavy</i>	Sink Traps
Bark, <i>loose</i>	Felspar	Madders	Slate Pencils
Bass Mats	Field Seeds	Marble, <i>in boxes</i>	Slates, <i>writing</i>
Beef & Pork, <i>in casks</i>	Figs	Mastic	Smalts
Bichrome	Files	Matchetts	Soap
Biscuit	Fish, <i>salt, casks & dried</i>	Mats and Matting	Sizing
Black Lead	Flax	Meat, <i>cured</i>	Soda Water
Bladders	Flocks	Millboards	Soldiers' Clothing
Bone Flats	Fry-pans	Millstones	Spades
Bones, <i>loose</i>	Galls	Molasses	Spetches
Boric Acid	Gambier	Mop and Broom Han- dles	Spoons, <i>iron</i>
Borax	Garancine	Moss, <i>in bales</i>	Starch
Boxwood	Ginger	Munjeet	Steel, <i>bars & bundles</i>
Brass Wire	Glass, <i>crown, in boxes & crates</i>	Mustard Seed	Sugar Mills
Bread	Glass, <i>window</i>	Naphtha, <i>in casks</i>	Sugar, <i>refined</i>
Bristles	— <i>rough plates</i>	Nuts	Sugar of Lead
Bricks, Bath or Flan- ders	Glue and Glue Pieces	Oakum	Sugar Moulds & Pans
Broom Heads	Grindstones	Oil, <i>in casks, except Palm</i>	Sulphate of Copper
Brushes	Grindery	Old Clothes	Syrup
Buckles, <i>iron</i>	Groceries, <i>general</i>	Oranges and Lemons	Tapioca
Butter, <i>in casks and boxes</i>	Gums of all sorts	Orchilla Weed	Tarpaulings
Buttons	Gun Barrels, <i>rough</i>	Osnaburgs	Terra Japonica
Camata	Gutta Percha	Paints	Tinical
Camatina	Hair, <i>plasterers'</i>	Palm Leaves	Tips
Candles	Hammer Heads	Palisades	Tobacco, <i>leaf</i>
Candlewick	Hams	Paper Hangings	Tous-les-mois
Canvas	Hardware, <i>packages above 5 cwt.</i>	Pearl Shells	Trees and Plants, <i>in mats, heavy</i>
Cardamoms	Hemp	Piassava	Trenials
Carpeting	Hemp Seed	Picker Bends	Turmeric
Carriage Springs, Axles, and Steps	Herrings, salt	Pins, metal, <i>in boxes</i>	Turpentine
Cheese, <i>except Stilton</i>	Hinges, iron	Provisions, <i>salt</i>	Twist, <i>cotton</i>
Chicory, <i>prepared</i>	Hoes	Potatoes, <i>preserved</i>	Twigs, <i>brown</i>
Chocolate	Holloware, <i>in hds.</i>	Pyroligneous Acid, <i>in casks</i>	Umbrella Stretchers
Cider, <i>in casks</i>	Hoofs, Cow & Ox, <i>loose</i>	Raisins	Valonia, <i>in sacks</i>
Cobalt	Honey	Reftners' Sweepings	Varnish, <i>in casks</i>
Cockles and Mussels, <i>at owner's risk</i>	Horse Shoes	Rice	Vegetable Wax
Cocoa Nuts	Horns, Cow and Ox, <i>loose</i>	Sad Irons	Veneers
Cocoa	Horn Tips, <i>loose</i>	Safflower	Vetigria
Codilla	Hurdles	Safety Boxes	Vetches, <i>small lots</i>
Coffee	Ice, <i>loose</i>	Safes, <i>iron</i>	Vices
Colours	India Rubber	Sago	Waste, <i>cotton and woollen</i>
Copper	Iron Bedsteads	Sal ammoniac	Washers
Cordage	Iron Liquor	Sarsaparilla	Warps, <i>cotton</i>
Cotton Waste	Iron Wire, <i>bright</i>	Sash Weights	Wet, <i>cotton</i>
Cotton Yarn	Ivory Black	Sassafras	Whetstones
Cowries	Kelp	Saws	Window Blinds
Cream of Tartar	Kips, <i>in bales</i>	Screw Jacks	Wire, <i>bright</i>
Crematine	Lac, <i>all sorts</i>	Screws, <i>iron</i>	Wood Acid, <i>in casks</i>
Cranberries	Lamp Glass	Scrows	Wool
Cudbear	Lard	Scythe Stones	Yarn, <i>linen and cotton</i>
Currants, <i>grocers'</i>	Lasts, <i>in hampers</i>	Seeds, Clover, &c.	Yeast, <i>casks, full loads</i>
Cutch	Leather, <i>undressed</i>	Senna	Yellow Berries
Divi Divi			Zaffers
			Zinc, <i>sheets, &c.</i>

THIRD CLASS.

Acetic Acid, <i>in casks</i>	Cider, <i>bottled</i>	Iron Fencing	Seal Skins, <i>dry</i>
Ale and Porter, <i>bottled</i>	Cochineal	Indigo	Sheep Skins
American Clocks	Cockles	Juice	Shoes, <i>in casks</i>
Angelica Root	Confectionery	Leather, <i>dressed</i>	Smallwares
Asparagus	Copper Rollers	Limpets	Snuff
Bales, Boxes, Cases,	Cork Wood	Linens	Spade Trees
Packs, and Trusses	Crucibles	Liquorice	Sponge, <i>in bales</i>
of Manchester and	Cutlery	Mussels	Stags' Horns
Barnsley manufact-	Drapery	Muskets, <i>in cases</i>	Stationery, <i>general</i>
ures, Scotch Cotton	Drugs, <i>boxes or ham-</i>	Mustard	Steel Toys
Goods and Irish	<i>pers</i>	Nails, <i>copper & brass</i>	Stoves, <i>common</i>
Linens	Fenders, <i>cast-iron</i>	Nux Vomica	Sugar Candy
Bark, Peruvian	Fire Irons	Ovens, <i>common</i>	Sweets and Cordials
Bees' Wax	Flannel	Oysters	Tapes
Bellows	Floor Cloth, <i>not ex-</i>	Packs and Bales	Tacks
Black Beer	<i>ceeding 10 feet long</i>	Paper, <i>fine</i>	Tea
Blankets	Fruit, <i>ripe</i>	Pepper	Tobacco, <i>manufac-</i>
Blowing Engines	Girders, <i>iron, exceed-</i>	Pelts, <i>dry</i>	<i>tured</i>
Books	<i>ing 20 feet in length</i>	Perry, <i>bottled</i>	Trays, <i>iron</i>
Boots and Shoes, <i>in</i>	Glass, <i>flint</i>	Periwinkles	Twigs, <i>white</i>
<i>casks</i>	Grapes, <i>owner's risk</i>	Pimento	Umbrellas
Butter, <i>in cools</i>	Grapes, <i>common</i>	Plumbago	Vegetables, <i>in baskets</i>
Calicoes	Goods, <i>heavy, not spe-</i>	Potatoes, <i>new</i>	Wadding
Canada Stoves	<i>cified</i>	Rabbit Skins, <i>dressed</i>	Whalebone
Candy Sugar	Guns and Pistols	Railway Tickets and	Wheels, <i>wood</i>
Counterpanes	Hair, <i>upholsterers'</i>	Cards	Wheels
Cards	Hardware, <i>light</i>	Saddlery	Window Frames, <i>cast-</i>
Cassia Lignea	Hatters' Stuff	<i>Ironmon-</i>	<i>iron</i>
Castor Oil	Hides, <i>dry, loose</i>	gery	Wine and Spirits, <i>in</i>
Cast-iron Pots	Hides, <i>grn. or market</i>	Saddlery	<i>casks</i>
Castings, <i>light</i>	Hooks and Eyes	Scale Beams	Yarn, <i>woollen and</i>
Cheese, Stilton	Horns, Stag	Scythes	<i>worsted</i>

FOURTH CLASS.

Acetic Acid, <i>carboys</i>	Garden Plants, <i>in</i>	Magnesia	Shoes, <i>in hampers</i>
Agricultural Imple-	<i>pots, and Seeds</i>	Marble Slabs	Sticks and Stails
ments	Garden Seats, <i>light</i>	Meat, <i>fresh</i>	Stoves and Grates, <i>po-</i>
Almonds	Gig Shafts	Naphtha, <i>in tins</i>	<i>lished</i>
Almond Oil	Goods, <i>Light, not spe-</i>	Nutmegs	Straw Plait, <i>light</i>
Aloes	<i>cified</i>	Needles, <i>in boxes</i>	Tamarinds
Amber	Handmills	Oil, <i>in jars and boxes</i>	Teazles
Anchovies	Hay Rakes, <i>in bundles</i>	Pickles	Tinware
Aniseed	Hay and Straw	Picture Frames	Tongues, <i>animal</i>
Balsams	Hops	Pipes, <i>Smoking</i>	Tortoise Shell
Baskets	Ink	Plated Goods	Travellers' Patterns
Bottles, <i>glass, white</i>	Isinglass	Poultry, <i>dead</i>	Tubing, <i>Copper and</i>
Brooms	Joiners' Work	Powder Blue	<i>Brass</i>
Butter, <i>in crocks</i>	Lace	Printers' Ink	Trays, <i>paper</i>
Calenders	Lamps	Puncheons, <i>new,</i>	Type
Canes	Light Goods, <i>not spe-</i>	<i>empty</i>	Varnish, <i>in tins</i>
Chandeliers	<i>cified</i>	Quicksilver	Wines and Spirits,
Cornice Poles	Looms	Quills	<i>bottled</i>
Crape	Luggage, Trunks, &c.	Rabbits	Woollen and Worsted,
Floor Cloth, <i>exceeding</i>	Machinery, <i>light</i>	Reeds and Rushes	<i>Goods, not elsewhere</i>
<i>10 feet long, not</i>	Machines, Weighing,	Salmon, <i>in boxes</i>	<i>specified</i>
<i>carried uncased</i>	<i>small</i>	Shovels, <i>wooden</i>	Yeast, <i>German</i>

FIFTH CLASS.

Bonnets	Embroidery	Glass, <i>stained and</i>	Silk, <i>manufactured</i>
Cabinet Ware	Essences	<i>plate, at owner's risk</i>	Silk, <i>raw</i>
Chairs	Essential Oils	Hats	Sponge, Turkey, <i>in</i>
China, <i>in boxes</i>	Feathers	Millinery	<i>cases</i>
Cigars	Fish, <i>fresh</i>	Musical Instruments	Statuary, <i>as per agree-</i>
Cinnamon	Furniture	Perfumery	<i>ment only</i>
Clocks	Furs	Pianos and Organs	Toys
Eau de Cologne	Game	Pictures	Turtle
Elephants' Teeth	Gloves	Poultry, <i>alive</i>	

AQUA FORTIS, VITRIOL, ARDENT SPIRITS, IN CARBOYS, GUNPOWDER, LUCIFER OR CONGREVE MATCHES, AND SUCH LIKE COMBUSTIBLE ARTICLES, NOT CARRIED ON ANY TERMS WHATEVER.

Engines and Tenders on their own Wheels:—For distances under 100 miles, 2d. per ton per mile; for distances exceeding 100 miles, 1½d. per ton per mile prepaid. Railway Wagons, new, 3d. per Wagon per mile. Contractors' Wagons and Materials carried upon the Railway Company's Goods Wagons:—for distances under 50 miles, 3d. per ton per mile; above 50 miles, 2d. per ton per mile.

Approved at a Meeting of Goods Managers, held in Manchester, 20th November, 1851.

BRAITHWAITE POOLE, *Chairman.*

N.B.—All Lists of Rates and Advertisements prior to this date, are hereby cancelled.

All minerals are specially subdivided from the first class, to accommodate those parties who provide their own wagons, and perform the service of loading and discharging the wagons themselves.

Aquafortis, gunpowder, lucifer matches and other articles of a combustible nature, being extremely dangerous in transit, are, or ought to be, when carried, loaded separately in safety vans on certain days, under strict surveillance, and always in sidings remote from stations. But no uniform system has yet been adopted for classifying the trains: on some lines, passengers are invariably conveyed separately from merchandise, whilst upon others, they are carried along with fish, fruit, meat, yeast, coal, lime, pigs and cattle, indiscriminately; but on those lines where the traffic is adequate, these varieties are despatched separately, when practicable.

It would be conducive to the interests of all parties, if a general classification of trains were arranged throughout the kingdom. It has been admitted that a great mistake has been made, on the long lines especially, in running all classes of passengers by the same train, thereby allowing those who pay third-class fares to travel with, and arrive at their journey's end, at the same time as those persons who pay first-class fares. Each class should be separated and run at different speeds upon all long and continuous lines, whereon the traffic is commensurate with the means of adopting that principle, instead of perpetuating the practice of charging three different prices for one and the same speed. In like manner, the perishable goods, dry goods, corn, coal and cattle, should be run separately, at proportionate and economically working speeds.

There are engines now running upon the narrow-gauge lines capable of drawing medium passenger trains at a speed of 60 miles an hour, and in course of time, passengers will probably be conveyed by the London and North Western Railway, from London to Liverpool, a distance of 200 miles, in four hours, or less.

If all trains were even now started to time, punctually, and not unnecessarily delayed at intermediate stations, such regularity would materially economize the working of the traffic; and the following appropriate average speeds of trains, stoppages inclusive, might at once be readily accomplished, and generally adopted:—

Classes.	Per Hour.		Day and Night.
	Summer.	Winter.	
	Miles.	Miles.	
Express Class . .	40	35	To be run by day-light, whenever practicable.
First do. . .	30	25	
Second do. . .	25	20	
Third do. . .	20	15	
Excursion do. . .	15	None.	
Goods, through . .	18	16	To be run by night, whenever practicable.
„ stopping . .	15	13	
Cattle, through . .	16	14	
„ stopping . .	14	12	
Coal, through . .	14	12	
„ stopping . .	12	10	

Numerous instances may readily be adduced, to prove the vast advantages and political economy of the railway system, without which, the penny postage could not have been achieved, nor the Great Exhibition rendered available to the multitude; the produce of the land and sea in vegetables, fruit, meat, fish, all provisions and fuel, would have remained as limited in consumption as heretofore, and the poor man's fireside in the rural districts would never have been warmed by coal. In Birmingham, before the establishment of railways, there were two or three fish-dealers only, whereas now there are sixteen; and the district is bountifully supplied with fresh fish of all kinds daily, from London, Liverpool, Hull, Yarmouth, Leith, Glasgow, Gloucester, Bristol, and other seaports.

It would be economy to give good pay to all railway officers and servants; their duties being more arduous and onerous than those of any other calling, entitle them to an adequate remuneration, and by paying them well, the shareholders retain the services of the most experienced men, who are invaluablely requisite to such undertakings.

If the coinage of the realm, the weights and measures, were all decimalized, it would be the means of saving £100,000 a year to the railway companies, in clerks and porters. Many other improvements suggest themselves, as the subject is more carefully contemplated; but a sufficient number of essential points are herein shown, to assist in forming an opinion of the economy of railways as a means of transit, comprising the classification of the traffic, in relation to the most appropriate speeds for the conveyance of passengers and merchandise.

[MR. C. MAY.]

Mr. C. MAY strongly objected to the principle of railway companies doing everything for themselves, and consequently, embarking in a variety of manufactures foreign to the real character of their undertakings. Individual enterprise would be crushed; and it was far from certain, that any economy would be effected, for experience had, on the contrary, generally shown, that the employment of paid officials was the most expensive mode of working which could be resorted to.

Mr. WYNDHAM HARDING said, that Mr. Poole had proved himself to be a most accomplished railway manager, and the activity of his mind had prompted him to look into matters which were not, absolutely, in his own department. He, however, could not agree with him in many points, as, for instance, the proposed division of the railway companies into four great districts: again, as to the uniformity so earnestly recommended, he believed, that it was impracticable to attain, and moreover, that it was not in the least desirable, as the system of everybody attempting to do everything, was one which never answered in an economical point of view, and had the injurious effect of putting a stop to all improvement. The only point in which uniformity was desirable, was the maintenance of one gauge throughout the country: he was a decided advocate of that of 4 feet 8½ inches. With respect to fares, all legislation on that subject was wrong in principle: each company should be allowed to feel its own way, and he had no doubt, that in the end, this plan would prove the most advantageous to the public. On the Glasgow and Paisley line, passengers were actually carried for less than the former Government tax,—one-eighth of a penny per mile; the consequence was, that the tax had been reduced to 5 per cent. He did not think, that it was advisable to fix, absolutely, certain rates of fare for certain speeds. This was a question which depended very much upon the different circumstances in which companies were placed: in one case, the extra express fare had been taken off, and the reduction was followed by an increase in the receipts.

Captain HUIGH said, it had been alleged, that it was injurious for railway companies to become manufacturers on their own account, but they were so, at present, to a great extent, and they had adopted this plan, not from choice, but from necessity. As an illustration of this, he would take the manufacture of rails. The competition in this article had become so keen of late years, that in order to keep down the price, the quality was deteriorated, and the rails manufactured within the last few years, would not bear comparison with those made twenty years ago. The serious loss and risk of accident continually entailed on the London and North Western Railway

Company from this cause, compelled them to turn their attention to the subject, and they eventually, but with great reluctance, decided on the erection of rolling-mills.

It was now too late to map out, and divide the kingdom into districts, as had been proposed. If on the first introduction of railways in England, the same course had been pursued as in France, there could be no doubt of the great advantage which would have accrued both to the companies and to the public; but the lines had now become too entangled to allow of such a plan being carried out. The railway system was, however, in a state of progress: thirty-seven lines were in direct connection with the London and North Western; still, these lines all differed, to a certain extent, with one another, and there was much yet to be done, before that uniform action could be insured, which was essential to safe and economical working.

It was now generally admitted, that the profit of a railway company, depended more upon the quantity carried, than upon a high price being charged for transit. A certain quantity of merchandise could always be calculated on, and although the prices paid for it were low, the speed was low also, and it was in the end, more profitable than the passenger traffic, which was, by its nature, very irregular. Whenever there were 150 tons of merchandise, which could generally be depended on, that quantity would give 6s. 3d. per mile; and after deducting one-fifth for the return of the empty wagons, there would still be left 5 shillings per running mile; it was, certainly, more profitable to carry coals at 5 shillings per mile, than passengers at 6 shillings, (which was the utmost that any railway produced,) when the great additional expenses attendant upon passenger traffic, such as stations, &c., were taken into account.

Mr. R. STEPHENSON, M.P., V.P., said, that in the infancy of railways, the Engineers were compelled to be the Managers also; at that time, he had considerable experience in the questions now under discussion, but of late years, he had not had the same opportunities: he would, therefore, confine himself to certain points which were more particularly connected with engineering. It had been stated, that the railway companies had been driven to manufacture their own rails, not from any particular profit to be derived from it, but from positive necessity, as the only means of obtaining a good quality. He thought it would be very generally admitted, that this was the only point in which they would succeed: in all others, individual manufacturers would advantageously compete with them. Had the Directors of the London and North Western Railway exhausted all other means of procuring a better quality of rails, before proceeding to manufacture them on their own account, they

would, doubtless, have been fully justified in taking this step: but such was not the case, and he believed, that the erection of the rolling-mills at Crewe would entail an unnecessary loss on the shareholders. They should have taken a more extended view of the matter, and have adopted the plan of the Birmingham and Derby Railway Company, who did not contract for their rails by public competition, (knowing, that if they were tendered for at a low price, they would, necessarily, be of an inferior quality,) but they applied to a contractor to furnish them with the best iron, at a fair price, and they themselves superintended its manufacture. The result was, that their light rails of 56 lbs. to the yard, made twenty years ago, were still in place, while those of the London and North Western, of 84 lbs. to the yard, supplied by public competition, showed signs of abrasion at the end of three months, and would soon require to be taken up. Nothing could be more conclusive against the evil effects of competition, with regard to the quality of rails.

Now with respect to locomotives: Messrs. R. Stephenson and Co. had, at first, constructed engines for the Liverpool and Manchester Railway, at £450 each, but finding that this sum did not cover the outlay, they were obliged to raise the price to £600 and then to £1,000, when the Company resolved to build engines for themselves. The first was said to have cost £400 less than they had been charged for similar engines, but on going into the particulars, it was found that the cost of the different items of materials, tools, coals, engine-power, capital, rent of workshop, and rates and taxes, had not been carried into the account, and that when these were added, the actual cost of this engine, (which, after all, was not very successful,) greatly exceeded the amount they had previously paid. So it must always be with every large company who undertook to make small articles; they lost the advantage of improvements, and of the division of labour. It would no more repay an Engineer to manufacture all that he required, than it would a watchmaker. Railway companies should, therefore, direct their attention, not to manufacturing their own rails, but to bringing about a better understanding between themselves and the iron-masters.

With regard to uniformity, the carriages should be, if possible, entirely similar in a few material points, so that they might travel with the same ease and safety, on all the lines, leaving scope for improvement in the details.

Captain HUIGH observed, that the London and North-Western Company had not resorted to public competition, but had applied to six or seven eminent firms. The directors did not fix a limit to the price, but they demanded a guarantee, that the rails should continue for two years, without abrasion, or lamination.

Mr. R. STEPHENSON, M.P., V.P., remarked, that to make the application to half-a-dozen firms was, practically, the same, as to submit it to public competition. In contracting for the rails for Egypt, he applied to a single good house, and appointed an agent to superintend their manufacture and to test them. The test employed was that fixed by the Sardinian Engineers,—a weight of from 2 to 3 cwt., falling from a height of 16 feet: defective rails were thus detected with more certainty, than by being merely submitted to a still weight, yet only one, or two of the rails in question, failed. He repeated his conviction, that it was only by private negotiation, that good quality could be insured.

Mr. W. HARDING was also of opinion, that very few articles could be manufactured by railway companies, without loss; certainly, neither rails, nor locomotives. The habit of always accepting the lowest tender had led to these difficulties, which the directors themselves were now deploring.

Mr. C. MAY said, that every director, individually, would, in his own affairs, buy the best article in the best market, but when they were united as a board, they stood in awe of the shareholders, and drove down the contractors to the lowest price. Blame was also to be attached to those who received the rails, as they must have been ignorant of the difference in quality of the articles contracted for, and those supplied.

Mr. HAWKSHAW remarked, that the fault was not altogether attributable to the boards of directors, but in a great degree, to the manufacturers; for the specification always stated, that the rails should be of the best quality.

He dissented from the opinion, that great advantages would have arisen, if the Government had laid down, at the first, the lines which were to be followed. It was quite true, that a great deal of money had been wasted, that many mistakes had been committed, and that a larger dividend might have accrued to the shareholder; but this was nothing, in a national point of view, in comparison with the evils which Government interference would have created. Rigid unbending straight lines would have been laid down, and thus have prevented that large amount of accommodation which was now secured to the different towns in the kingdom. It must be confessed, that railways had been constructed with too great rapidity, but after all, they were not so badly devised; and the system followed in England had allowed of a certain competition, which was to the interest of the public, although perhaps, not to that of the shareholders.

Mr. B. POOLE said, he might have extended the Paper, by

showing the great reduction in the rates of carriage which had been effected by railways. For instance, the canals between Liverpool and Birmingham formerly charged from £2 to £5 per ton, and that was the rate originally adopted by the railways, but it was now reduced for the bulk of the traffic, more than 50 per cent., the rates being from 10 shillings to £2 per ton. By so arranging the traffic, that the wagons should be filled both ways, there would be a saving to the railways of 30 per cent. He could not agree in the sweeping denunciation of companies who made their own articles: for example, the price charged for gas, between Liverpool and Manchester, was 4s. 6d. per 1,000 cubic feet, while the same quantity, manufactured by a railway company, cost only 2s. 6d. at Crewe and at Chester.

Mr. C. H. GREGORY bore testimony to the ability of Mr. Braithwaite Poole's Paper, with many parts of which he agreed.

He thought, that the importance of the electric telegraph, in promoting the economy of railway working, had been very properly insisted upon. On a railway of which he was the Engineer, it had become his duty to investigate the savings which might be anticipated from the use of the electric telegraph, and he found, that the annual charge at which the Telegraph Company offered to supply and work the telegraph, very little exceeded the saving which would be effected by its use in the diminution of useless piloting, and the avoiding of the unproductive running of carriage and wagon stock; while the additional advantages of increased safety and efficiency, and the enlarged capabilities of working induced by the electric telegraph, contributed to render it of inestimable advantage to the railway system.

He agreed in the importance of dividing, as far as possible, large and heavy trains into smaller trains, which were more manageable and safe, believing that the undue size of many trains, had frequently been productive of great inconvenience and danger. He advocated the use of permanent and fixed covers to goods wagons, not only because they contributed to economy of repairs, but because they also saved a large amount of the manual labour required to 'sheet' a train with tarpaulins, an operation which, on the old system, occupied a great number of porters for a long time. The use of spring buffers and traction springs in goods wagons was also strongly to be recommended, as saving the wagons from the violent blows to which they were subject in shunting, and thereby very materially diminishing the cost of repairs.

He deprecated the adoption of any rigid uniformity which should limit the advance of improvement; but when any forms, or dimen-

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sions had been found by experience, to be good, he considered, that uniformity in these particulars was desirable, until other forms, or dimensions had been found to be better. In ordering large quantities of rolling stock, he had adopted uniformity for the frames of all descriptions of passenger carriages, and the wheels and axles of all carriages and wagons, were made to the same templates. The wheels and axles, and the principal working parts of the engines, had also been made to the same templates. Such a uniformity, where practicable, he had found to lead to facility and economy in repairs, and to save expense in spare stock.

The extent to which railway companies should manufacture their own stock, was a question requiring much consideration. He was not prepared to advocate their manufacturing their own stock exclusively, because such a measure would limit the improvement and economy which enlarged competition produced. But as railway companies were obliged to keep up large establishments for their repairs, he considered, that they might, to a certain extent, manufacture their own stock with advantage, without any great increase of their establishments, and insure, at the same time, the best materials and workmanship. He could confirm these views, from his own experience in the manufacture of carriages and wagons.

He thought, that Mr. Poole's proposal for the territorial division of the railway system of the country into four great systems, or companies, was open to great and radical objections. It would check that emulation among Companies and their officers, which was, at present, highly conducive to economy and improvement; and not only would the public be prejudiced by the uncontrolled monopoly of districts, but he believed the actual gross revenues of the Companies would be diminished, as the systems would be too large for individual management, and the Companies, as at present divided, could more completely develop the local resources of traffic. The proposed measure would also be politically objectionable, from the enormous commercial powers which would be vested in the amalgamated Companies; and the plan was to be deprecated, as leading to a system of centralization, which had not been attended with successful results, when applied to the great objects of national industry.

Mr. J. LOCKE, M.P., V.P., said, that he was under great disadvantage in supporting different views to those which had been advocated by so distinguished an authority: still his experience had led him to opposite conclusions on this point. At an early period, the Grand Junction Company bought all their locomotives from manufacturers, and it was only justice to admit, that those of Messrs. R. Stephenson and Co. were the best. But the engines were, neces-

sarily, in need of constant repair, and an establishment was formed for that purpose, at Crewe. Then arose the question, whether this establishment could not be advantageously used, not only for the repair, but also for the construction of engines. The plan was tried, and all the engines for the Lancaster and Carlisle, for the northern section of the London and North Western, and for the Chester and Holyhead Railways, were built there; and the cost was found to be much less than the prices they had formerly paid. He admitted, that railway companies did not show the expense in such detail as individual manufacturers, but even if the latter could produce at less cost, it must be recollected, that by this plan, the companies saved the 20 per cent. profit, which, it might be presumed, the manufacturers added to the prime cost. But the great question for railway companies was to consider, whether the machinery necessary for repairs, was not precisely that required for construction: if so, to build their own engines was not to embark in a new undertaking, but simply to extend one already in existence. Again: the mechanics who repaired the engines saw their defects, and consequently, were better able than others to guard against them, in the construction of new ones: besides, there were many parts of an old engine which were not worn out, and could be advantageously worked into the one which was to replace it. These were, evidently, powerful inducements for a Company to manufacture their own engines: and the same remarks were applicable to the carriages and wagons. In 1837, the Grand Junction Company constructed their own carriages; subsequently, when supplied for a time by manufacturers, they were found to be very inferior. It was, of course, desirable, both for facility of working and economy in manufacture, that the different parts, such as wheels, axles, &c., should be made uniform, and that there should be identity between certain leading dimensions.

Referring to the Paper of Captain Huish, it was there stated, that 'facing-points' were formerly numerous, but had now been almost abandoned: he doubted whether such was the fact, and he was inclined to think, on the contrary, that of late years, they had rather increased. It was also remarkable, that superiority was claimed for wooden wheels: his impression was, that by far the greater number of wheels on the London and North Western, were of iron, and that they were now made so perfect, as scarcely to admit of any improvement. The mode of coupling the merchandise wagons was pointed out as a source of danger; this was not attributable to any fault of construction, but to the habit of allowing carriages, vans, and trucks, to be all promiscuously mixed up in the same train. The question of the expediency of laying down additional

lines of rails, on account of the crowded state of the traffic on certain lines, had been set at rest by the experience gained during the Great Exhibition, and by the introduction of the electric telegraph: but whatever might be the amount of traffic on a line, if sufficient station-room were provided, there was not, as far as existing lines had been developed, any necessity for resorting to that expedient. He was not prepared to admit, that it was necessary for a signal to be seen at a distance of 1,500 yards: he thought a distance of from 600 to 800 yards, quite sufficient for all purposes. Level crossings were, no doubt, a source of danger, but he did not think they could be avoided to any great extent. Without them, it would be very difficult to carry railways through agricultural districts, for if Companies were compelled, in every case, to build bridges, the cost of construction would not allow of that cheap conveyance, which was one of the greatest elements of success in these undertakings. He cordially concurred in the tribute paid by Captain Huish to the engine-drivers, than whom, a more competent class of men it was scarcely possible to find. It might be desirable, that they should be good mechanics, but this was not essential; for during a combination of the engine-drivers on the Grand Junction Railway, a great number of the cleaners were employed in that capacity, and several of them had become the best drivers on the line.

Mr. R. STEPHENSON, M.P., V.P., said, that the question could only be determined by a detailed comparison of the working expenses of companies and manufacturers, and he was convinced, that the result would bear out his opinion. The assumed 20 per cent. profit of the latter was a pure chimera: so far from this being correct, he could state that on £240,000 worth of machinery made by Messrs. R. Stephenson & Co. during the last two years, there had been an actual loss of £1,200. In addition to the Crewe establishment, which had already cost £100,000, the London and North Western Company were about to expend £15,000 on a rolling-mill; this, at least, was a perfectly new undertaking, and one which could only result in a loss.

Mr. J. LOCKE, M.P., V.P., explained, that he did not support the system of a Company manufacturing their own rails; he only advocated the expediency of their building their own engines, and to that extent, using their own material.

Mr. SLATE said, that if the relative amount of the tenders sent in for the large engines recently made by Messrs. Sharp, Brothers, and for which the Crewe manufactory competed, could be ascertained, it would be at once seen, which was the more economical system.

Mr. VIGNOLES did not agree in the opinion, that the result of the Companies building their own engines, would be the introduction of

improvements in the construction: those hitherto effected, were entirely due to the competition among the manufacturers.

Mr. W. HARDING said, that he had read a Paper before the Statistical Section of the British Association in 1848:¹ wherein he stated the results which differed from those in the Paper of Mr. Poole, more especially with regard to the amount of saving that had been effected. He did not approve of the suggestion of discarding the tarpaulins of the goods wagons: on the Great Western Railway, this system of covering was preferred by both the agents and porters, to any other. As to the great question of railway companies becoming their own manufacturers, he thought it was a most fatal doctrine, as far as the pecuniary interests of the companies were concerned, and contrary to the first elements of political economy, which demonstrated, that individual manufacturers must, necessarily, be able to supply the article cheaper than any large company. The steam-hammer, for instance, had become an important and economic instrument, but only on condition that there was always work enough for it to do, otherwise, it would considerably add to the expense, and as the London and South Western Railway had repaired their engines very effectually without it, it was evident that all the machinery necessary for construction was not required for repairing only. It was also important in this question, not to lose sight of the fact, that one great cause of the depreciation of railway stock, was due to these continual additions to the capital account: the French lines had only cost £13,000 per mile, whilst the English lines had cost at the rate of £40,000 per mile, and the capital account was not yet closed. He did not think a perfect uniformity of parts very desirable, for it stood in the way of improvement; it was sufficient, in his opinion, that the heights and distances between the buffers should be identical on all lines.

Mr. BIDDER said, that he was not convinced by the arguments which had been advanced in favour of railway companies becoming manufacturers, and he was entirely at issue as to the facts. The two main points put forward were, first, that the companies always possessed the necessary tools for the construction of engines; and, secondly, that they saved the contractor's profit. As to the 20 per cent. spoken of, he did not believe it possible, that any large manufactory could ever yield so large a profit. With regard to the first point, all experience had demonstrated, that those who were employed by others, never worked so economically as on their own account. Superintendents of locomotive establishments were not likely to pause to inquire, as a private manufacturer would,

¹ *Vide Journal of the Statistical Society of London*, vol. xi., page 322.

whether the outgoings were exceeding the incomings of the establishment. No change in the directorate of a railway would ever make any alteration in this respect. Now if there was one thing which a railway might be supposed to manage better than another, it was the maintenance of the permanent way; yet on the northern division of the London and North Western Railway, the maintenance of the whole of the permanent way was let out, in short lengths, to contractors. Again, they could possibly manufacture their own gas at less than half the ordinary cost; but this was a very small item, and if instead of carrying out these simple measures of economy, they preferred embarking in a most complicated manufacture, they could not possibly succeed.

He had been rather disappointed in the character of Mr. Poole's Paper, which pointed out the small economies which railways might effect, instead of giving, as he had hoped, the results of the experience of the Author as to the general management of traffic. He had expected information on the policy of railway companies working together, and thus benefiting each other, instead of embarking in that ruinous competition of which the East Anglian and Norfolk Railways were examples. The interests of all railways were bound up together; the prosperity of one extended to others, and its depression was equally felt by all. The conclusion at which he had arrived was, that the railway system would never prosper, until all the lines were worked by contract, and the unseemly quarrels of directors, secretaries, and managers no longer interfered with their success.

Mr. C. MAY said, that he had examined the balance-sheet of Messrs. R. Stephenson and Co., and that it was even commercially worse than had been stated, for no interest had been charged on capital. It was highly honourable to the head of that firm, that he had dared, (which few would have done,) to announce the fact, that skill, even under favourable circumstances, had actually resulted in loss. The cause of this was evident: seven years ago, the great demand, and large prices given for engines, induced the erection of a large number of establishments, for which an adequate amount of work was not now to be found: prices had, consequently, diminished to such a point, that many establishments had only the choice of giving up at a great loss, or going on at a small one. Again, the specifications were now drawn out so stringently, that their provisions could not be practically enforced; fair manufacturers had thus been driven out of the field, inferior articles were supplied and accepted, and the Boards of Directors had defeated the very objects they had in view, in submitting their contracts to public competition. So far from thinking it a profitable undertaking for railways to manufacture

their own engines, he doubted whether it would not even be better policy to organize a system of contract for their repairs; he believed, that the constant exercise of individual superintendence and enterprise which this system would insure, would, in the end, prove to be the more economical. He was convinced, that it would be much better, not only for the railways but also for the public, that the question of railway economy should be examined in the broad point of view which had been just indicated, rather than be confined to the minor points suggested in the Paper.

Mr. BRUNEL, V.P., said, that having been connected with Companies which had fallen into the assumed errors, he would state the result of his experience on the subject. He did not think, that as a general rule, it was profitable for Companies to manufacture their own engines, but he believed that, at present, such a course was unavoidable. In some articles of manufacture, for instance, it was often the only means of insuring a desirable quality. But he was strongly opposed to any railway company expressly setting up manufacturing establishments, as they could not advantageously compete with individual enterprise. With respect to engines, when a large number were employed, it was necessary to have, at all times, a great many skilled workmen, for examination, cleaning and repairs, to have large and costly tools, and a certain amount of material, and he thought, that the spare time of the operatives, and that the tools could be profitably employed in constructing new engines, and that, within these limits, it was both politic and economical so to do. Thus he differed from the principle laid down, that Companies should never manufacture, while he objected as strongly as others, to their embarking in any new undertaking, such as making their own rails.

It had been stated, that the great competition which had been excited, was the cause of an inferior quality being supplied: but surely, if manufacturers chose to tender at too low a price, this could be no justification for not acting up to the conditions they had voluntarily accepted. He felt great pleasure in testifying to the fact, that all the engines which had ever been supplied to him by Messrs. R. Stephenson and Co., had been beautifully constructed, and honestly delivered according to the stipulations.

He differed as to the views expressed, that manufacturing was one of the causes of depreciation of railway property: it had not, within his knowledge, been carried out in England to such an extent, as to affect the return upon the whole capital. No company had 10 per cent. of their capital embarked in manufacturing, and even at the worst, supposing the loss to be one-half, it could not account for the diminished value of railway property. Any comparison of the,

cost of English with that of foreign railways, must be fallacious: the American lines, for instance, generally passed over a country, in which there were no vested interests, while the vast sums which English railways had to disburse on this account and in the purchase of land, were, unfortunately, notorious. In speaking of the expenditure caused by vested interests, he referred to the great cost of the works, rendered necessary by the existence of roads, canals, &c., which had to be respected.

Mr. B. POOLE said, that his statistics as to passengers, had been taken from parliamentary documents, but those as to merchandise, from other sources; he had never seen Mr. Harding's Paper. His object had been, to point out every particular, in which experience had led him to believe, that economy could be effected, and it was for that reason, he had alluded to the stationery, the domes of the engines, &c. The saving in the manufacture of gas, he had particularly noticed, and the advantage of having warehouses for the coke instead of wagons, and always keeping on hand a sufficient stock for two months' consumption. When he recommended the division of the country into four great railway sections, he had in view a plan, which, by the amalgamation of the rolling stock, would, he was convinced, be attended with very great economy.

Captain HURSH said, that the question of railway accidents had been entirely lost sight of, and that the whole discussion had turned upon the comparative cost of manufacturing by companies, and by individuals. With regard to the particular instance referred to, he might state that, in 1851, a number of engines were required by the London and North Western Company for the Exhibition traffic: they were to be of a particular description never yet made by the company, and they were wanted in a very short time. Application was made to Crewe, but it was found they had none of the patterns, and that they could not supply the engines in time. No tender was sent in from Crewe, but an estimate was made, which was rather higher than that of the manufacturers who obtained the order. The contract was not fulfilled in time, yet the manufacturers lost by it £8,000. Upon the broad question, whether railway companies having large establishments, could manufacture engines, with advantage to themselves, his experience on the London and North Western Railway had convinced him, that they could make them both safer and cheaper than manufacturers. He could not see the great distinction which it had been attempted to establish, between repairing and constructing: constant alterations and repairs became, eventually, in many cases, positive re-construction. The London and North Western Company had bought three hundred engines, of which the carriage to their destination had alone cost £80 each, and they had

manufactured three hundred ; the latter lasted longer than the others and worked better : the stock, at present, was five hundred and thirty. He thought, that experienced carriage-builders were all in favour of wooden wheels, which were 10 per cent. more durable than those made of iron ; in the six cases of breaking which had occurred during four years, four were iron wheels, and two, wooden wheels. The iron wheels were fast disappearing, and in six, or eight years, there would be scarcely one remaining : the present proportion was 1,837 carriages with wooden wheels, and 1,748 with iron wheels, and those of all the new carriages were of wood. These observations had reference, of course, to passenger carriages only.

The fallacy of attributing the depreciation of railway property to the Companies having undertaken to manufacture for themselves, had been already pointed out : the capital thus engaged, was too insignificant in amount, to make any great figure in the capital accounts. The real cause of injury was the number of branch lines which had been executed. The question of maintenance of way had not been fairly put : the contracts were made many years ago, and as they had fallen in, the maintenance of those portions of the line had been retained by the company, whilst the numerous branches of the Grand Junction Railway were not contracted for at all. He perfectly agreed, that gas could be advantageously manufactured by railway companies, and he had endeavoured to carry out that system. The inevitable tendency of a railway company was to extend the principle of doing as much as possible for themselves, especially when they found, that they could rely upon the quality of the articles which they had hitherto manufactured.

Mr. HAWKSHAW was also of opinion, that the real aim and intent of the Paper had been lost sight of, and injustice done to the Author, by confining the discussion to the narrow limits of a manufacturer's question. With regard to Captain Huish's Paper "On Railway Accidents," no one could be better able to give information upon so important a subject, as that which he had brought under the notice of the Institution. He differed from him, however, on some points. The fracture of rails was, no doubt, formerly, a frequent source of danger, especially in winter, but when heavier rails were introduced and the sleepers were laid closer together, fractures became comparatively rare. He had increased the weight from 56 lbs. to 82 lbs. per yard, with advantage. Danger would arise from heavy locomotives running at great speeds, upon lines with old light rails ; and he was obliged to admit, that the quality of the rails had, of late, so considerably deteriorated, that it, sometimes gave ground for uneasiness. The manufacturers had competed so keenly,

that they had reduced the prices, to their own detriment. He quite concurred in the condemnation of self-acting points; it was safer to rely for good working, upon the intelligence and attention of the men employed. The effects on the permanent way of the alternations of weather were referred to, as constituting another danger, but this could be obviated, by exclusively using broken stone for ballast through which the water would pass, instead of being retained.

The table of the causes of failure in engines, was particularly valuable, showing, as it did, that very few were of a dangerous character. Out of one thousand cases, there was only one of explosion of the boiler: whereas the frequency of bursting of the tubes, showed the safety of this class of boiler for using high-pressure steam. On the whole, not 4 per cent. of these failures could be productive of accidents. It was gratifying to find so few accidents in the carriage stock: he thought, that the construction of iron wheels was brought almost to perfection, and that safety could hardly be increased by superseding them with wood. Danger arising from heated axle-boxes might be partially obviated, by doing away with sand-ballast, which was objectionable in many respects. With regard to the principle of uniformity, he thought it might be enforced, with great advantage, for the width of way, for the height of the buffers, and for all couplings; but it should not be extended to construction, as it would have a tendency to restrict improvements. Covered vans were, no doubt, preferable to the system of tarpaulins, for any line that had a great number of merchandise wagons.

He did not agree with the Author, as to the advantages of the semaphore signal: it required also an auxiliary signal, and was, therefore, in his opinion, too complicated. He preferred a distance signal, placed at 600 yards beyond the station and capable of being seen 600 yards further on the line.

It would have been desirable, if a classification of the accidents on railways, with reference to their presumed causes, could have been given, in the Paper: it would have helped to elucidate many questions, and have probably led to some practical conclusions. The railway board merely gave the number arising from causes beyond the control of the passengers, and the number occasioned by their own carelessness: these were satisfactory, so far as they went, and proved, that the railway system was raised to great perfection, since in the last three years, it was chargeable with only one death among seven and a quarter millions of passengers, the other two being attributable to the fault of the individuals themselves.

A railway company with which he was connected had made many locomotive engines, but never with the view of saving the manu-

facturer's profits. The motives which induced them so to do, were various, and he was satisfied, that they had acted judiciously ; but he would not lay down as a general rule, that it was always advisable for railway companies to manufacture for themselves. He believed, that experience would eventually point out the course which it was most expedient to follow, and which would not necessarily be the same for every Company.

Mr. FAIRBAIN was convinced, that no joint-stock company could successfully compete with individual manufacturers, either as to price, or quality. The former had not that powerful inducement of pleasing their customers, nor did they feel the necessity of always striving for improvement.

Lieutenant-General Sir CHARLES PASLEY said, that the accidents he had had occasion to investigate, were chiefly those which had been fatal. He had always found the greatest difficulty in ascertaining whether they arose from the rails, or from obstructed machinery : but he thought, that heavy rails with short bearings, conduced very much to increase the safety of a line.

Mr. R. STEPHENSON, M.P., V.P., said, that because few accidents had arisen from broken rails, it must not be inferred, that fractures seldom occurred ; and that so far from heavy rails being safer than light ones, his experience showed that, on the contrary, fractures became more frequent, as the weight of the rails and the speed of the trains were increased. On the Shropshire Union, there were more broken rails, now that the weight was 82 lbs. to the yard, than formerly, when it was only 56 lbs. : four or six fractures now occurred every week. The rails were in lengths of 16 feet, with five sleepers to each rail, and it was possible, that the system of cross sleepers and chairs increased the susceptibility to fracture. He was inclined to believe, that lighter rails and longitudinal sleepers would, eventually, prove to be the best.

Major-General MACNEILL said, that he had had great experience upon this point in the United States. The rails were, generally, 56 lbs. to the yard, and were laid on sleepers, 3 feet apart : they were almost all imported from England. Except on one line, where fish-bellied rails were laid down, he had rarely seen a fracture ; and he did not think, that a single accident had occurred, which was not owing either to carelessness, or to neglect of orders. The heaviest engines weighed 20 tons ; they were four-wheeled, and the driving-wheels were 5 feet in diameter : the speed was 25 miles per hour. The best engines were imported from England ; those supplied in 1832, by Messrs. R. Stephenson and Co., were still in excellent working order.

Mr. P. W. BARLOW observed, that on the South Eastern Railway, where the rails were 70 lbs. to 80 lbs. per yard, he had never seen a single case of fracture.

Mr. BRUFF said, that a very important point had been raised, as to the possible increase of danger, from the sleepers being too far apart, and he thought it was a question, whether it would not be better to increase the quantity of timber, rather than that of the iron. On the Eastern Union Railway the goods trains and engines were heavy, and the speed great, yet hitherto, there had not been a single case of fracture: the rails were 72 lbs. to the yard, and the sleepers were from 2 feet 6 inches to 3 feet apart.

Captain HUISE could corroborate the opinion, that as the rails had increased in weight, so had the fractures increased in number. The old 56 lbs. rails lasted very well, and neither broke, nor laminated, whereas those of 82 lbs. did both: the quality had so much deteriorated, that he had seen one of the latter break into three pieces by falling from a waggon. He agreed, that a classification of accidents would be an interesting and valuable document, if drawn up with care, and it might lead to measures whereby their occurrence might be prevented, or their severity be mitigated. One remarkable fact, which had been already elicited from an analysis of them was, that the results of accidents at high speeds, were, very frequently, not so serious as those which happened with low speeds. This view was borne out by an examination into the position of the carriages which were most injured, when an accident occurred at a low speed. As an illustration, he would cite the most severe which had happened on any English railway, that at Wolverton, where seven people were killed. The effect of the shock was almost inappreciable at the head of the train, the buffers of the engine were not broken, the tender was not injured, nor any of the carriages until the middle of the train where a second-class carriage was completely doubled up. The train was going at the rate of 10 miles an hour. Had the speed been greater, it was more than probable, that all the carriages would have escaped, but as it was, there was time for the rear part of the train to make its momentum felt, and to meet the recoil of the springs, like a returning wave, half way. He believed, that the immense majority of accidents would be found to be owing to carelessness on the part of the railway servants.

Mr. R. STEPHENSON, M.P., V.P., concurred in the view, that the elasticity of the timber might be more important than the rigidity of the iron; but then, the very important question of cost had to be taken into consideration. He thought Mr. W. H. Barlow's system of permanent way, made altogether of iron in one piece, might be an

improvement, as it combined the two qualities alluded to, but whether the form was the best, or whether it was applicable to all climates, and to any kind of ballast, was a question upon which experience had yet to decide. He might mention, that when he was Engineer to the South Eastern Railway, he had seen many cases of fracture of the rails.

Mr. CAWLEY said, that on the Lancashire and Yorkshire Railway, some of the light rails of 56 lbs. to the yard, proved to be very bad. The defect was, undoubtedly, in the quality of the iron, for while one portion stood exceedingly well, the other was quite brittle.

Mr. RENDEL,—President,—hoped, that Captain Huish would continue to prosecute his useful and valuable researches into the causes of railway accidents, and the means of avoiding them, and that he would, from time to time, give the Institution the benefit of his experience.

May 4, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

The following Candidates were balloted for and duly elected:—Major-General William Gibbs MacNeill, U.S., and James Sims, as Members; Colonel Samuel Colt, U.S., Captain Robert Fitzroy, R.N., John Brogden, Jun., James Forrest, Henry O'Hagan, and Richard Alexander Robinson, as Associates.

The discussion upon the Papers, No. 877, "Railway Accidents, &c.," by Captain MARK HUIH, and No. 875, "The Economy of Railways, &c.," by Mr. BRAITHWAITE POOLE, being renewed, was extended to such a length as to preclude the reading of any other communication.

After the Meeting, Mr. Ebenezer Goddard, (Assoc. Inst. C.E.,) of Ipswich, exhibited in the Library, a small portable asbestos gas-stove, for heating apartments, of great simplicity and portability, the apparatus being contained in a box 12 inches by 9 inches, and 3½ inches deep; also a protected gas-burner of novel construction, for gas cooking-stoves, in which the holes were not in any way liable to be choked up.

May 11, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

The discussion upon the Papers, No. 877, "Railway Accidents, &c.," by Captain MARK HUIH, and No. 875, "The Economy of Railways, &c.," by Mr. BRAITHWAITE POOLE, being renewed, was extended to such a length as to preclude the reading of any other communication.

May 18, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

The following Candidates were balloted for, and duly elected :
—Messrs. Eugène Flachat, George Harrison, and John Thomas Woodhouse, as Members ; Peter David Brown, Lieutenant William Chapman, B.E., Lionel Gisborne, and Thomas Thorneycroft, as Associates.

No. 870. "Observations on Artificial Hydraulic, or Portland Cement ; with an account of the testing of the Brick Beam erected at the Great Exhibition, Hyde Park." By GEORGE FREDERICK WHITE, Assoc. Inst. C.E.

IN the Session of 1838, a description was given, at one of the Meetings of the Institution, of the brick beam which was built by Messrs. Francis and White, at their cement works, Nine Elms, and which, after standing eighteen months, was broken down in the presence of many professional and scientific gentlemen.¹ In the discussion that ensued upon this communication, as well as upon that furnished by Mr. Brunel,² who, about the same period, instituted many important experiments upon the strength of Roman Cement, in connexion with bricks, several interesting facts were elicited and principles were deduced from them, which have since served to regulate professional practice, in the employment of these materials.

Since that date considerable improvements have been made, both in the manufacture and uses of cement, amongst the most remarkable of which, may be cited the introduction of the artificial substance, called Portland Cement.

The adoption of these artificially compounded materials, in preference to those made from natural cement stones, has for some time been gaining ground in this country. Before proceeding to detail the experiment which has influenced this communication, it is necessary to glance very briefly at the causes which seem to justify such a preference, in order to show, that a well-compounded artificial cement possesses for certain purposes, decided advantages both over limes and natural cements.

The property, inherent in the natural hydraulic cements, of setting rapidly under water, is their principal characteristic, and it is not too much to say, that but for this important quality, many of the great works of the present century, amongst which the Thames Tunnel stands pre-eminent, could never have been

¹ *Vide* Minutes of Proceedings Inst. C. E., vol. i. (1838,) p. 16.

² *Vide* *Ibid.* p. 20.

executed. The chief application of cement in this country, is in connexion with bricks, which being of small dimensions and readily handled, can with the exercise of ordinary care, be adjusted in position, before the cement begins to set, even though it be used pure. The setting process once accomplished, the action of hardening progresses gradually; but for practical purposes the consolidation is equally effective at the end of twenty-four hours, as at the end of as many days. The properties, however, which render cement valuable as a connecting medium in brickwork, operate unfavourably to its use in masonry, since with all the care that can be taken, waste from rapid setting will ensue, and to avoid the loss consequent on such waste, it is very common to re-work, or chafe up the cement, thereby interfering with the setting process, which once disturbed, is never again resumed. It is this cause mainly, that prevents the use of Roman Cement in bedding stonework. The cement becomes partially set before the blocks are placed *in situ*, and no permanent adhesion takes place, a result not attributable to want of affinity between these materials, since it is shown by experiment, that under favourable circumstances, it possesses extraordinary powers of adhesion even to granite and the hardest stones. The prejudice entertained in France against quick-setting cements, made from the natural stones, has led to the extensive use in that country, of the hydraulic limes, which in some cases, are used with an admixture only of sand, in others with Pozzolanos, or Trass, and, (when these are not easily procurable,) with the artificial Pozzolanos, made of calcined clays.

The abundance of this last-mentioned class of ingredients led, at one period, to their somewhat general adoption in France, and though successful in some cases, it is notorious, that in the majority of instances, where the artificial Pozzolanos have been used on a large scale, failure has followed. Such was the case at Algiers, at Cherbourg, and at Rochefort, where the mortar maintained its favourable appearance for three, or four years, but eventually crumbled and entirely disintegrated.

M. Vicat, (who, amongst the Engineers of modern times, has perhaps most scientifically and successfully prosecuted the study of this subject,) examined closely the causes of these failures, and came to the conclusion, that the hydrochloride of magnesia, which is contained largely in the sea-water, penetrated the imperfectly carbonated portion of the cement, and by occasioning a mode of crystallization different from that of the ordinary carbonates of lime, led to the disintegration of the whole mass. He was thus led to believe, that the character of the Pozzolanos produced by volcanic heat, must

differ from those produced by artificial means, and the inference to be drawn from his observations would be, that to create a perfect cement, it is necessary to mix the clay with the carbonate before calcination.

Upon this basis the subsequent investigations of M. Vicat and his followers appear to have been conducted.

Contemporaneous with these researches in France, were those of Mr. Frost in this country, who was the first manufacturer of artificial hydraulic cement on a large scale; but from the circumstance of his not applying to his mixture the needful amount of calcination, Mr. Frost's cement, though of good colour and economical in cost, did not attain to the average strength of Roman Cement, nor did it possess sufficient excellence to dislodge that material from its place in public estimation.

The published experiments of General Pasley, made at the same time and in conjunction with Mr. Frost, are known to all who take an interest in such matters. The General appears to have shared in the opinion of Mr. Frost, that artificial cements well and skilfully made, would supersede the natural cements, and in the investigation of the subject, he tried many experiments on the various proportions in which the carbonates and the clays should be blended together to effect the desired object; and though it does not appear that he succeeded in producing a cement of greater adhesive, or resisting power, than the best Roman Cement, his patient and laborious investigations have been of signal service, not only to manufacturers of cements, but to all who employ them in works of construction. It will thus be apparent, that the problem yet remaining to be solved, was that of producing, by the judicious combination of carbonate of lime and alumina, a cement superior to those resulting from the calcination of the natural stones.

This desideratum has apparently been attained in the Portland Cement, which is a material at once combining the characteristics of the best cements, with the peculiar properties of limes; that is to say, of a lime, when used in conjunction with a large amount of foreign matter, as sand, or gravel, or, when fully dosed with water to form grout; under either of which conditions it sets very slowly, but with great eventual hardness;—and of a cement when mixed with the smaller proportions of sand, &c. ordinarily allotted to cements, in which case it sets with nearly the same rapidity as Roman Cement, but with much greater hardness. That this two-fold property is almost peculiar to Portland Cement, and is not shared by those made from the natural stones, proof is found in the fact, that the ordinary Roman Cement is rarely mixed with

a larger quantity than two volumes of sand to one of cement, that it is not used for concrete, and that when employed as grout, its setting properties are so much injured, as to leave it questionable whether its application in that manner, adds at all to the solidity of the construction. On the other hand, it is well ascertained, that four, five, and six parts of sand may be mixed with Portland Cement to form mortar, the proportion, less, or more, being a question of the time that can be afforded for setting, and not one of deterioration of quality from excess of foreign matter. Of its uses both as concrete and grout, subsequent mention will be made.

The process employed in the manufacture of Portland Cement, (so called from its resemblance in colour to Portland stone,) is in most respects, similar to that adopted by Mr. Frost and General Pasley in making their artificial compounds.

Chalk and clay, mixed in certain definite proportions, are carefully ground together in water, and the mixture is then run off into backs, or reservoirs. After attaining a specific consistency, it is artificially dried and is then removed to the kiln for calcination, which operation is carried to a much greater extent than that needed for lime and Roman Cement.

It is next delivered to the mill for grinding, and after being sifted is packed for use, the important points of uniformity in colour and in time of setting having been previously ascertained by repeated experiments. Daily trials of the strength of the cement are made by moulding it into bricks, (vide Appendix, Experiments on Cohesion, Fig. 3, pp. 500 and 501,) which in twenty-four hours after setting, are exposed to rupture by extension, in order to prove the cohesive power.

This is the mode adopted by the French Engineers for testing the quality of the cement employed in the Government works.

The progressive increase in the strength of the cement is quite remarkable. In seven days, it attains a cohesive power of more than 100 lbs. per square inch, and at the end of three months, these bricks will require more than 2,000 lbs. to break them, a strength equivalent to 414 lbs. per square inch; as in the case of one, made of Portland Cement of ordinary quality, broken at the Exhibition in September, 1851 (vide Appendix). Another plan adopted in France of testing the hardness of cement, is by means of a machine fitted with a pointed rod, which being allowed to descend with force upon the specimen of cement placed beneath it, determines by its degree of penetration, the extent to which the material has indurated. The amount of this penetration is expressed by a graduated scale on the upright rod of the machine.

Though too minute to be employed in testing large deliveries of
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cement, it is nevertheless useful for determining the setting power, particularly under water. A sketch and description of this instrument is given in M. Vicat's work on Cement.¹

The numerous operations involved in the production of Portland Cement sufficiently distinguish it from the natural cements, the manufacture of which consists in burning the stone in open kilns, to the extent needed to deprive it of its carbonic acid gas; in grinding, and afterwards filling it, as delivered from the mill, into packages for use, a simple and economical operation. To the variety then of the processes, to the extra fuel employed, and to the time and care expended upon the manufacture, the cost of Portland Cement is attributable, and not to the materials of which it is composed, which in themselves are simple and inexpensive.

In an interesting communication lately made by M. Vicat in the "*Annales des Ponts et Chaussées*," there occur some important observations on the mixture of cement with lime mortar, coupled with an investigation of the properties of cement burnt, as he terms it, "*jusqu'à ramollissement*," by which is doubtless intended the softening, or melting, which takes place when the clay begins to vitrify. In his first experiments on the blending of the natural cements with the artificial hydraulic limes, M. Vicat mixed the cement with the lime during the process of manufacture, while it was in a state of paste, but he found, that the tardiness of the operation needed for the production of the mixtures, entirely deprived the cement of the energy of its first setting, which coupled with the expense of the compound, induced him to relinquish the plan. Facts that subsequently came to his knowledge, caused him to resume the study of the subject, and he found, that by adding cement to the lime, when in a state of mortar, and not during the process of manufacture, the energetic properties of the cement were not interfered with, and that the mortar so treated, possessed remarkable powers of resistance to the action of sea-water.

An important fact developed during these investigations was, that the stalest cements impart the most hydraulic properties to the lime; a circumstance to be accounted for, perhaps, on the principle, that the lime in the cement, having parted with its energetic properties, by the absorption of moisture from the atmosphere, and the alumina being then the predominant element, the stale cement acts the part of Pozzolano, and imparts the hydraulic character to the lime mortar with which it is mixed. The experiments made on

¹ Vide "A Practical and Scientific Treatise on Calcareous Mortars and Cements, Artificial and Natural," &c. By L. J. Vicat. Translated by Capt. J. T. Smith, M.E. London, 1847. Plate 2.

blocks of *béton* formed of this cement mortar, show that by the mixture of 6 parts of lime to 10 parts of cement, a cohesive power equal to that of the best natural hydraulic limes is given; while a less proportion of lime, say from 1 to 5 parts mixed with 10 parts of cement, only produces the same effect as the Pozzolanic mixtures,—the addition of the cement causing an extra cost of about 50 per cent. per yard cube of mortar.

It must be noticed in the experiments detailed by M. Vicat, that the blending of fresh cement with the lime was attended with only partial success, for a mixture made of 10 parts of cement and 8 parts of lime, and which occupied sixteen days in setting, could be pierced by the drill to the depth of one-fourth of an inch, and after immersion during eleven months it lost superficially all consistence, and was penetrable nearly three-eighths of an inch before arriving at the quick; which shows, that deterioration took place after setting, and brings in question the expediency of mixing lime with fresh cement in important hydraulic works.

The same proportion of stale cement mixed with lime, set in two days, and showed a resistance to the drill, just four times in excess of that offered by the mixture made of lime and fresh cement. The mortar made with stale cement and lime has the farther advantage of speedily becoming very hard on the surface, and thus covers itself with a crust sufficient to oppose the shock of the waves and the rolling of the shingle; thus allowing the interior to attain a proper amount of cohesion, and to arrive progressively at its ultimate degree of hardness. It is, however, obvious, that the cases in which the cement would require through staleness, (*i. e.* from the re-absorption of carbonic acid, or moisture from the atmosphere,) to be re-invigorated by the addition of lime, are in this country at least, of unfrequent occurrence, and since it is not contended, that these mixtures furnish results which can be put in comparison with those of the cements themselves, it is only in such instances as the exportation of cement to distant countries, where the interval between its manufacture and its use, has been so considerable as to occasion staleness, that such a practice could be recommended for adoption. In the before-mentioned communication of M. Vicat in the "*Annales des Ponts et Chaussées*," there occur some observations on what he terms "*Ciments brûlés*," as opposed to the "*Ciments cuits*," in which he notices especially the Portland Cement. He says:—"The setting action of these cements is variable,—in some cases being accomplished in an hour,—in others only after an interval of weeks." The difficulty of grinding them and the quantity of fuel required in their calcination are, in his judgment, insuperable obstacles to their adoption, but he

states, that if their property of progressive hardening and their cohesive powers be examined, they will be found quite remarkable, and greatly in excess of the best natural hydraulic limes,—200 lbs. per square inch being the greatest resistance to compression, eventually attainable by the limes, while these highly-calced cements acquire that hardness in a few days, and will at last reach 700 lbs. per square inch, a resistance superior to that of the calcareous lithographic limestones.

Two volumes of sand reduce this resistance to about 350 lbs. per square inch, or one-half; but it is not the less true, that these cements resolve the problem of producing an artificial stone, that shall be equal in hardness and density to compact limestones.

As a matter of comparison it may be noted, that the eventual resistance to compression of Portland Cement is, when used pure, 2,000 lbs. per square inch,—with two volumes of sand it is 1,250 lbs., and as a concrete stone it is about 1,750 lbs. per square inch;—forces greatly in excess of M. Vicat's trials.

Of the Portland Cement, M. Vicat observes, that it possesses all the properties of the over-burnt cements, with a moderately quick-setting power, that its density is 1.50, the density of ordinary cements being taken at 1.00, and that its chemical analysis is precisely that of a very eminently hydraulic lime. "The most noticeable fact," he says, "in these cements, is their great hardness and the resistance they consequently offer to the combined action of the sea and shingle in the most exposed situations, agencies which very speedily destroy the Pozzolan mixtures and the best hydraulic limes. . . . By these alone it is possible to effect the monolithism of great masses, entirely homogeneous and resistant in all their parts, and arriving after a few months, at the hardness of compact calcareous stones. To attain this object, it is indispensable to employ the slow-setting cements, which will allow of to-morrow's work following upon that of to-day without dis-connection, or break,—a result which it is impossible to arrive at with the ordinary quick-setting cements."

The agency to which cements owe their power of setting, and consequent induration, is not generally well understood. It has been commonly considered, that this action is due to absorption by the cement, of carbonic acid gas from the atmosphere, during the process of setting; but it seems now to be ascertained by chemists, that it is only partially to this cause, that the hardening of cements is attributable; that it is in fact, the chemical union of the lime with silica and clay, and the consequent formation of a double silicate of lime and alumina, that produces the effect, without

which, cements placed in positions where air cannot penetrate, would never harden. It is, however, well known, that cements used under water, become as compact as when exposed to the air, and that in the interior of large concrete blocks, the process of induration is not less complete than it is on the outside, making due allowance for the increased hardness imparted to the surface of the block by the action of the atmosphere, which, however, is only superficial in its effects.

With lime the case is different. In its pure state, unmixed with clay, lime hardens solely by the absorption of carbonic acid from the atmosphere, and is thus partially re-converted into its original condition of carbonate of lime, but inasmuch as the quantity of this gas contained in the atmosphere is limited, the operation of it upon limes is slow and feeble, hence the proverb, that "time at a hundred years is a child;" and hence also the fact familiar to all, that the rich limes used as mortars in the hearting of very thick walls, do not harden, even after the lapse of many years. It will thus be seen, that for the hardening of the rich limes, the presence of air, and consequently carbonic acid, is essential, while for the water-limes in which clay exists in small proportions, and for the hydraulic cements into whose composition it largely enters, the influence of this gas is comparatively unimportant, nature having afforded another and more efficient means for the completion of the hardening process. The peculiar affinity of the lime for the alumina and silica, appears to be exerted most powerfully with those cements, whether natural, or artificial, which are most highly calcined, and consequently, set the slowest. To this cause then, must be referred the excellence of the artificially-produced Portland Cement. The proportions in which the ingredients are mixed, favour a high degree of calcination; slow setting is the consequence, and the final result is a degree of hardness superior to many kinds of stone. The slowness of its setting may prevent the employment of this cement for masonry set in water, (particularly running water,) except in a pure state, which increases the cost; but it is not the less true, that the tardiness of its action, insures for the work executed with it, a degree of ultimate solidity, so superior to that produced by the quick-setting cements, as to more than compensate for what would, at first sight, appear to be a disadvantage.

The uses of Portland Cement in the several applications of concrete, mortar, and stucco, are extremely various. The use of concrete made of lime, in those positions where heavy superstructures demand a more efficient base for their support, than is afforded by the soil alone, has become so common, and its appli-

cation is so generally attended with success, that it will be needless to notice here more than one form of its employment,—that of concrete blocks, a mode of constructing great masses which recommends itself equally on the score of economy and simplicity.

To Mr. Ranger is due the credit of having first attempted in this country on any considerable scale, this method of construction in important works. The blocks he used were composed of lime, sand, and gravel in due proportions, and no pains were spared to insure the rapid setting of the lime, as well as the perfect incorporation of the materials. They were not, however, found capable of resisting frost, and the action of heavy bodies striking against them, and, though disintegration of the parts did not ensue, to the same extent as in the blocks at the French ports, already referred to, the failure was sufficiently marked to prevent any further adoption of the plan, and was naturally calculated to produce in the minds of Engineers, a prejudice against the use of concrete for such purposes, which it has required time and further experience to dispel.

The large proportion of sand and gravel that can be mixed with Portland Cement without materially affecting its cohesive power, gives it an immense advantage over lime, which though cheaper in first cost, cannot be safely mixed with much more than seven times its volume of foreign matter.

While it is not disputed, that if sufficient time be allowed for their induration, blocks made of lime and Pozzolano will, in time, attain a cohesion quite sufficient for the interior parts of Breakwaters, or Dock walls, it is emphatically by the substitution of Portland Cement in place of lime, that such an entire consolidation of the several materials can be effected, as shall set at defiance the action of frost and the force of the waves, and by thus realizing the perfect homogeneity of great masses, re-establish the confidence in such constructions which previous experiments had tended much to weaken.

Some account of the employment of Portland Cement for concrete blocks, in the Government works of this country and of France, will afford the best criterion of its adaptation for such purposes.

At the Government harbour of refuge works at Dover, under the superintendence of Messrs. Walker and Burges, these blocks are extensively used for that part of the hearting of the breakwater, which being under low-water mark, cannot be filled in with concrete en masse. The cubic contents of these blocks vary from 45 feet to 120 feet, and the weights from 3 tons to 7 tons; the dimensions of width and depth being generally equal, and the length about twice the width. The composition and the mode of construction are very simple.

One cubic foot of cement, measured dry, is mixed with 10 to 11 cubic feet of shingle from the beach, (consisting of large and small clean shingle and coarse sand in nearly equal proportions,) in a box holding as much material as will form one block, the cement and shingle being spread in alternate layers until the box is full. One side of the box being then withdrawn, the contents are allowed to fall gradually on to the mixing platform, where water is added, and the concrete is made, which is then shovelled into moulds of the required size, in which it is allowed to remain about twenty-four hours, until it is sufficiently set to permit the sides of the mould to be removed. The blocks so made then stand for eight, or ten days, and are then conveyed either into their positions in the work, or are, more usually, piled up for stock. The holes for the lewis penetrate two-thirds of the entire depth of the block, and are formed during the filling process, by inserting bevilled wooden plugs, which are withdrawn when the block is hard. The labour attendant on cutting the lewis holes, as in stone blocks, is thereby saved, and the risk of fracture is also diminished by the precaution of forming the holes nearly, if not quite through the block. It will, however, give some idea of the cohesive power of the concrete to state, that on the tenth day after being made, blocks of 3 and 4 tons weight have been lifted by lewis sunk only 8 inches into the mass.

The large blocks of 112 cubic feet when moulded contain about 13 feet cube of dry cement and 136 cubic feet of dry shingle,—total 149 cubic feet—a proportion of about one in eleven, showing a diminution of bulk of about 25 per cent., by the agglomeration of the materials, in the transition from the dry state to that of concrete.

The great hardness and cohesive power of these blocks, and the success which has attended their manufacture, (scarcely one per cent. of the whole number made having been broken,) show this to be a suitable proportion for the blending of the materials.

At the harbour of refuge works of Alderney, under the direction of the same Engineers, a similar application of concrete blocks is made as at Dover, with this difference, that in their manufacture, rubble-stone, which is very abundant in the island, is mixed with the shingle.

The proportions adopted are, one part of cement, two parts of sharp sand, and four parts of coarse and fine shingle; these materials, converted into concrete and thrown into the moulds, in quantities of 8 or 10 bushels at one time, suffice to form a layer over the whole surface of the mould. Flat pieces of rubble-stone, varying in size from 3 inches to 20 inches in length, are then imbedded pro-

miscuously in the concrete, and this operation is repeated till the mould is filled. The quantity of stone thus incorporated in the block, is found to constitute about 40 per cent. of the whole bulk, and the proportion of cement to the mass is one in ten, as at Dover.¹ Lewis-holes are formed as the work proceeds, and these blocks, like those made at Dover, are ready for moving in about ten days. They contain from 60 to 100 cubic feet, and their weight is from 4 to 6 tons, reckoning 16 cubic feet to one ton. The degree of smoothness and external finish given to the blocks, depends chiefly upon the quantity of water used in mixing the concrete. If guaged soft, the cement will find its way to the sides and surface, and will give an even face to the concrete, which in time becomes intensely hard, and as serving to protect the interior from the action of the sea, when the blocks are used in external walls, it is perhaps preferable to leaving them with a rough and honeycombed face, the result of using but little water in mixing the concrete. It is not, however, found needful to observe this precaution at Dover and Alderney, since at both places, the blocks are used exclusively for the hearting, or for the foundations of the walls, and are consequently, not in permanent contact with the sea and the shingle. The blocks are set by the diving-bell at Dover, and by men in diving-dresses, at Alderney, and are bedded dry, their close contact with each other, and their position in the wall, rendering the use of cement unnecessary, except to point the joints externally as the work proceeds.

The blocks made at the important works of the Digue at Cherbourg, where Portland Cement is largely used, are of enormous size, and are made in a different manner to that adopted either at Dover, or at Alderney.

The dimensions of those made at Cherbourg, are 12 feet long, 9 feet wide and 6 feet 6 inches deep, giving a cube of 712 feet, or 52 tons. These masses are constructed like rubble masonry without moulds, and are built up at low-water in a position convenient to the work. When made, they are slung to pontoons and floated at high-water to the point where it is desired to sink them, and then deposited "*à blocs perdus*" at the extremities of the Digue, near to the upright wall, in order to break the force of the waves at its foot and to prevent the disruption of the masonry. The object of making blocks of such immense size, is to secure their remaining perma-

¹ It is to be observed, however, that the introduction of rubble-stone, by confining the cement within a smaller compass, gives additional strength to the connecting material. Pro-tanto, therefore, the rubble-blocks have a greater power of cohesion than those made of shingle, in which the cement is equally distributed through the entire mass.

nently where they are deposited, the calculation being, that the waves would not have power to move masses exceeding 20 tons in weight. It has not, however, been found, that even these immense monoliths can always resist the motive power of the waves, for on more than one occasion, they have been thrown up whole and unbroken from the bottom to the top of the breakwater wall, a height at least of 30 feet. The mortar used in the construction of these blocks, consists of one part of Portland Cement to three of sand, which materials unitedly occupy from 30 to 40 per cent. by measure, of the whole mass.

In the communication before referred to, M. Vicat draws some conclusions with respect to these masses. He states that after testing the relative strengths of the blocks made at different places, *e. g.* Fort. Boyard, (Charente Inférieure,) at Marseilles, at Algiers, &c., he finds, that the mean cohesion of a mass of concrete launched into the sea from the land, must be about 60 lbs. per inch square, and that if deposited by sea, it must be from 40 lbs. to 45 lbs. per inch square, while it must have a cohesion of 25 lbs. per square inch, to resist simply the shock of the waves, when it is once in position, and in a state of unyielding solidity. It must not be inferred, however, that the long-continued action of marine forces during a course of years, will not affect masses having these degrees of cohesion; on the contrary, "Granite itself yields to their influence. Art can do little against time. Its mission is to construct and keep up works for a certain period, the measure of the efforts to be employed in so doing, being regulated by the joint considerations of economy and the intended limit of their duration."

"It has been found, that the strongest impulsive force that the waves can exercise, over a surface of a metre square, (an area equivalent to nearly 11 feet English,) is 30,000 kilogrammes or 30 tons, equal to 40 lbs. per square inch of compressive force, and answering to 9 lbs. on an average of resistance to tension for the same unity of surface." In comparison with these data, may be noticed the results afforded by concrete stone blocks of Portland Cement. Their interior cohesion becomes, in the end, very considerable, and exposed to crushing by hydraulic pressure, these blocks show, after nine months, a resistance of 113 tons per square foot, or more than 1,700 lbs. per square inch, which is but little inferior to Portland stone, while their power to resist tension is 200 lbs. on the superficial inch.

Another method adopted in this country, of forming concrete stone blocks, is to mix the cement with the stone in a state of grout. The stone is placed promiscuously in the moulds, and when one-third full, the grout, composed of one part cement and three parts sand, is poured in till the interstices are thoroughly filled up. It is true,

that blocks so made require longer time for induration than those made with cement stiffly gauged, but their ultimate solidity and the thorough homogeneity of the mass, is evidenced by a specimen sawn from the heart of a block made of grouted cement and Kentish rag-stone, which has in twelve months, acquired such hardness, that the cement is scarcely distinguishable from the stone to which it adheres. In situations where gravel is scarce, and where time can be given for the induration of the blocks, this mode may be adopted with advantage.

It is very questionable if sufficient importance is attached to the principle of ramming concrete, whether used en masse, or formed into blocks. To adopt that process with a quick-setting cement, mingled with only twice its bulk of sand, is to destroy the setting, or crystallizing action of the cement and to render it valueless, but in the case of lime, or Portland Cement, where the mixture of foreign matters is very large and the process of setting is slow, no such result takes place, and it is submitted, that the practice of consolidating the concrete by beating, immediately on its being deposited in place, would tend greatly to increase the density and solidity of the mass, which effect is further aided by the diminished quantity of water employed in mixing.

The best practical exemplification that can be given of this opinion is the material called 'Artificial Granite.' It consists of Portland Cement driven into intimate contact in iron moulds with fragments of Portland stone, by sharp and often-repeated blows, and the union of the two materials is the more remarkable, because it can be effected almost in a dry state, and with scarcely more water than is given out by the stone in the process of concussion. The uses of such a material, which is made to take any shape according to the moulds employed, are obvious:—pipes, sewer-blocks, landings, pavements, and even walls, are some of the applications which have been made of it by the inventor, who has found its duration as a pavement, in some very exposed situations, superior to that of Yorkshire stone.

The extremely close adhesion of this cement, under all circumstances, to Portland stone, gives rise to the speculation whether, or not any chemical action is exerted upon the cement by the stone, which is a pure carbonate of lime. The absorbent properties of the stone are doubtless a mechanical means of producing close contact, between the two bodies; but it is also possible, that a certain quantity of carbonic acid is given out by the stone and absorbed by the cement, which is thus more speedily carbonated than it would be, if it were placed in contact with siliceous bodies, such as flint pebbles,

round which, as nuclei, the cement crystallizes, by the mere force of molecular attraction.

A corroborative proof, that some such action takes place with limestones, is that sandstones, though equally absorbent, develop properties of adhesion to the cement, far inferior to those of Portland stone.

Mr. Burnell, in his excellent treatise on Cements and Limes, hints at the possible affinity of these substances for the limestones. In page 77 of his work, is the following passage:—¹

“Broken limestone appears to add very much to the qualities of concretes, bétons, and mortars. Very probably this may be attributed to the affinity between the molecules of the already-formed carbonate of lime, and that which is in process of formation; the new crystals may group themselves more easily about bodies whose form is similar to the one they are to assume. Or possibly there may be a tendency in the chemical elements to arrive at a state of equilibrium; and the carbonate of lime may, therefore, be supposed to part with a certain portion of its carbonic acid gas.”

The experiments made on the adhesion both of Portland and Roman Cements to various stones, and which form an Appendix to this Paper, tend to prove, that their adhesiveness is greater to Portland than to any other description of stone.

The average of these trials shows, that a force of 5,276 lbs. or nearly 2½ tons, was required to tear asunder two blocks of 6 inches cube, (vide Appendix, Fig. 2, pp. 499 and 500,) jointed with Portland Cement,—being 146 lbs. per square inch of sectional area; while with granite, Bramley fall, and Whitby stone, the resistance was but 97 lbs. 76 lbs. and 57 lbs. respectively, on the square inch. On reference to these experiments, it will be observed, that the joint between the cubes of stone was barely one-eighth of an inch in thickness, and that the stone was broken before the separation of the joint could be effected; and the results further show, that the connecting power of Portland Cement is, compared with Roman Cement, as 3½ to 1. The following is a résumé of the trials by compression, made on blocks 9 inches square and 18 inches long, the pressure being exerted on the ends of the blocks.

	Tons.	
Roman cement and two parts sand bore	5·33	per square foot.
Portland ditto and three ditto	44·00	ditto.
Roman ditto, pure	50·00	ditto.
Portland ditto and two parts sand	80·00	ditto.
Portland ditto, pure	146·00	ditto.

¹ Vide “Rudimentary Treatise on Limes, Cements, Mortars, Concretes, Mastics, Plastering,” &c. By G. R. Burnell, C.E. 8vo. London, 1850. Page 27.

The relative order of strength of the different mixtures is exhibited in this table, and as a matter of comparison.

Portland cement pure is 3 times the strength of pure Roman cement.

Ditto and two parts sand are $1\frac{1}{2}$ times the strength of pure Roman cement.

Ditto and three parts sand are equal to pure Roman cement.

The experiments on cross-strain tried at the Great Exhibition, give the following order of resistance. They were made on beams of pure cement, supported at both ends, and loaded in the centre, 4 inches in depth by 4 inches thick, with a clear bearing of 16 inches.

Portland cement, pure,	99 lbs.	per square inch.
Portland stone,	80 lbs.	ditto.
Sheppy cement,	61 lbs.	ditto.
Harwich ditto,	24 lbs.	ditto.

The Brick Beam, erected at the Exhibition Building, was constructed for the purpose of testing the comparative strength of Portland and Roman Cement, in the direction of the cross-strain, and of showing the adhesiveness of Portland Cement to bricks. It was built at the Great Exhibition Building, in Hyde Park, and was broken down in the presence of the Jurors of Class 27, and of numerous scientific and professional gentlemen. The size and form of the beam approximated, as nearly as circumstances would permit, to a beam of similar character described in the second edition of General Sir C. Pasley's work on Cements, and in the Transactions of the Institution.¹

That beam was made at the suggestion of Mr. Brunel by Messrs. Francis and White at the Cement Works, Nine Elms, in the year 1836 for the express purpose of testing Roman Cement on a large scale. The Roman Cement beam was built of hard stock bricks, bonded in the usual manner, and set in Roman Cement, gauged with an equal portion of sand grouted and made solid throughout: fifteen lengths of hoop iron were imbedded in the lower courses.

The whole length of the beam was 24 feet 4 inches, and it consisted of nineteen courses, measuring in depth 57 inches. The thirteen upper courses were two bricks, or 18 inches thick, and the six lower courses were two and a half bricks, or 1 foot $10\frac{1}{2}$ inches thick. The sectional area was consequently—

¹ Vide "Observations on Limes, Calcareous Cements, Mortars, Stuccos, and Concrete, and on Puzzolanos, Natural and Artificial," &c. By Major-General Sir C. W. Pasley, K.C.B. Second edition. Part I., page 164. London, 1847. Also "Minutes of Proceedings Inst. C.E.," vol. i. (1838), page 16.

39 inches by 18 inches = 702,

18 inches by $22\frac{1}{2}$ inches = 405

1,107 superficial inches sectional area.

It was supported at both ends, leaving a clear bearing of 21 feet 4 inches between the piers, in the centre of which were suspended the testing weights. When the beam had been erected three months, the testing was commenced by loading it with 11,200 lbs., with which weight it was left until the expiration of another three months, when the load was increased to 24,000 lbs. With this weight suspended, it remained for twelve months longer, (making in all eighteen months,) when it was determined to load it till it broke down, and this was accomplished with 50,652 lbs.

The beam built at the Exhibition Building was constructed with hollow tubular bricks, in compliance with a suggestion, that the use of these bricks in lieu of the ordinary solid bricks, would add much to the interest of the experiment.

The Portland Cement was used with an equal measure of sand, the iron hooping was inserted as in the Roman Cement beam,¹ and

¹ The objection invariably taken to the insertion of iron hooping in trials of this nature, would have determined its exclusion in the present instance, but for the fact, that the experiment being a comparative one, it was necessary to make the condition of both beams identical in every particular. The hollow brick beam, therefore, contained the same number of lengths of hoop iron as the Roman cement beam, though differently placed, for whereas the whole of the iron in the Nine Elms' beam was disposed in successive courses below the line of the neutral axis, the hooping in the Exhibition beam was, through a mistake of the workmen employed in its erection, so laid, that a considerable portion of it was either in the line of, or above the neutral axis, and thus practically useless. This error arose from placing the iron in the same relative position in each beam, though the courses built with the hollow bricks were much deeper, and consequently, fewer in number, than those built with common bricks, and the result was to deprive the iron hooping in the Exhibition beam, of about one-half of the strength that it may have imparted to the other beam. But since the collective value of the iron was only equivalent to a bar $1\frac{1}{2}$ inch by 1 inch, which bar, placed in the most advantageous position, viz., beneath the lowest course, and at the remotest point from the neutral axis, would have borne a permanent strain of only 12 tons, and seeing that in the position it really occupied, the efficacy of the iron was limited to about two-thirds of this strain, it will hardly be contended, that the hoop-iron exercised any perceptible influence in stiffening the beam, or that it was an important element in its construction. One proof, at least, to the contrary, was shown at the time of testing, when the hoop-iron in the lowest courses where the tension was greatest, did not break, but drew out, thus showing, that it was not rigidly confined between the bricks, and could not, consequently, contribute efficiently to their support.

the two beams were as similarly constructed as the tubular bricks would permit, but inasmuch as these were all laid as stretchers, the beam virtually consisted of forty tubes, (the number of bricks comprising the section,) open from end to end, having merely the narrow rims abutting against each other, instead of the solid sides and ends of ordinary bricks, and placed in courses alternately flatwise and edgewise, (vide section, Plate 5). These circumstances occasioned some variations in the sectional area and depth of the beam which, with the vacuities of the tubular bricks, must be taken into account in comparing the relative strength of the two beams.

By an inspection of the Diagrams (Plate 5) it will be readily seen, that as the vacuities are distributed throughout the whole depth of the beam, they occasion a loss of strength proportionate to their whole extent, varying of course as their distances from the neutral axis, but, as the solid parts of the section are similarly circumstanced, these vacuities are by no means analogous to such omissions as are sometimes made near to the neutral axis of iron beams, by which, metal is saved without a proportionate reduction of their strength.

The Portland Cement beam was supported on piers, like the Roman Cement beam, and the weight was, in the same manner, suspended over the clear bearing of 21 feet 4 inches.

On Saturday morning, the 20th September, the loading was commenced, and when it had reached 15,000 lbs. the beam was left with this weight suspended, till 1 o'clock on Monday the 22nd, when being found free from any deflexion, crack, or indication of failure, the loading was resumed until it was weighted with 40,000 lbs., at which time, a deflection of nearly one-eighth of an inch was observed; with 41,600 lbs. a crack in the centre of the beam was noticed, and soon afterwards, two cracks exhibited themselves in the four lower courses, at a short distance right and left of the centre line; with 51,600 lbs., the cracks extended through the six lower courses, and the deflection increased to 5-16ths of an inch, and with 62,800 lbs. which it bore for a short time, the beam gradually separated into two parts, as nearly equal as possible, the line of fracture being vertical, and indiscriminately through bricks and joints as they occurred. In falling, the beam thrust the piers considerably out of their vertical position.

The hollow tubular bricks averaged $5\frac{1}{2}$ inches wide, $4\frac{1}{2}$ inches thick, and 9 inches long, and the rims, or substances of the sides were 7-8ths thick: consequently, the hollow portion of each brick was equal to 9 superficial inches. The beam consisted uniformly throughout of ten courses, five of which were laid flatwise and five edgewise. The seven upper courses, including beds and joints,

measured 36 inches by an average of 17·25 inches, and the three lower courses 16·5 inches by an average of 26·6 inches:—

The gross sectional area was, therefore . . .	1,060 inches.
From which, deducting the vacuities in the	
40 bricks of 9 inches each	360 inches.

There remains a sectional area of . . . 700 inches.

The depth of the Portland Cement beam was but 52½ inches, whereas that of the Roman Cement beam was 57 inches. There was, therefore, for the Roman Cement beam, an area of 1,107 inches and a depth of 57 inches = 63,099 inches, whilst for the Portland Cement beam, there was an area of 700 inches, and a depth of 52½ inches = 36,750 inches, as expressive of the relative strength of the two beams, supposing them to have been built of the same materials.

The Roman Cement beam, as before stated, was broken down with 50,652 lbs., and since 63,099 : 36,750 :: 50,652 : 29,500, it follows, that if the Portland Cement beam had been broken down with 29,500 lbs., the two cements would have shown equal strength, but inasmuch as it required 62,800 lbs. to break down the Portland Cement beam, the experiment exhibited a superiority of Portland over Roman Cement in the ratio of 2·128 to 1 or full 2½ to 1. Or had the Portland Cement beam been built with solid bricks, and been of equal sectional area with that built of Roman Cement, it would have required 107,787 lbs. to have broken it down.

The experiments appended to this description, show the superiority of Portland Cement in a much greater degree, but when the nature of the structural defects attendant upon the use of tubular bricks is taken into account, and it is considered, that the Roman Cement beam had been built eighteen months, before the breaking weight was applied, whereas the Portland Cement beam was loaded with its breaking weight within five months of the time of its erection, it is not to be expected, that this experiment with the hollow bricks, would exhibit the full strength of the Portland Cement.

Of Portland Cement as mortar.—The adhesive quality of this cement to bricks, is seen by the foregoing experiment, to be of an intimate nature. The mixture of four parts of sand with one part of cement, forms a mortar which may be relied on in ordinary work, and is the proportion which has been used for some years at the Houses of Parliament. In arches, or other work, where rapid consolidation is required, less sand will of course be used ; but where time is not an object, there seems hardly any limit to the quantity of sand which the cement will carry, provided only the grit be sharp and clean.

In testing the resistance to compression, of brick piers built with

cement, the average resistance is found to be about 38 tons per square foot, but as Roman Cement is nearly always, and Portland Cement invariably, stronger than ordinary bricks, it is not in these experiments, that the peculiar properties of the cement are developed.

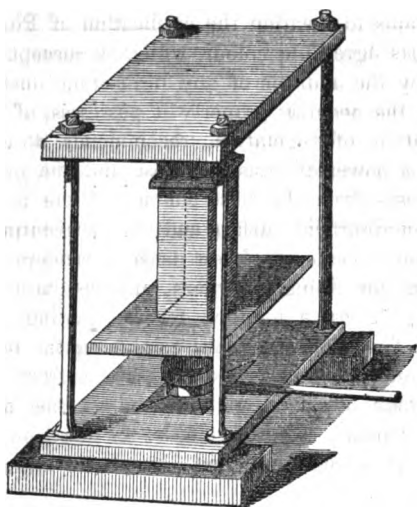
It only remains to mention the application of Portland Cement as a stucco. Its agreeable colour, which is susceptible of further improvement by the addition of any light stone dust, or of white sand, joined to the peculiar property it possesses, of resisting frost and the formation of vegetation, recommends it as an external covering. This power of resisting frost and the humidity of the atmosphere, arises from the close contact of the particles, which, producing a non-absorbent surface and thus preventing the disintegration common to cements of less density, renders it a peculiarly suitable material for lining reservoirs, cisterns, baths, &c., and has also caused its extensive adoption for the casting of ornamental figures, statues, fountains, &c., thus combining the appearance and durability of stone, with the economy resulting from the use of the mould, rather than of the chisel, which, if not the most legitimate application of cement, is one which, by its increasing demand for objects of art at a minimum cost, has been largely sanctioned and encouraged.*

The Paper is illustrated by a series of Diagrams, from which Plate 5, and the Woodcuts, figs. 1 to 4, (vide Appendix,) are compiled.

[APPENDIX.]

APPENDIX.

Fig. 1.



EXPERIMENTS on the relative resistance to 'COMPRESSION' of PORTLAND and ROMAN CEMENT, manufactured by J. B. WHITE and SONS. The Trials were made by Hydraulic Pressure, on Blocks 9 inches by 9 inches, and 18 inches long, (Fig. 1,) at the Iron Works of Messrs. GRISSELL, in December, 1847, under the direction of Mr. J. M. RENDEL (President Inst. C. E.). The power of the Press was 75 tons, and the pressure was exerted on the ends of the Blocks.

Size of Blocks, 9 inches by 9 inches; Sectional Area, 81 inches.	Days old.	Remarks.	Crushing Force in Tons.		Lbs. per Square Inch.
			On the Sectional Area of 81 inches.	On the Square Foot.	
<i>Blocks of Cement, pure and with Sand.</i>					
1. Pure Portland cement . .	30	{ Corner broken off but not otherwise injured . . . }	75	133	2·074
2. Portland cement . } 1 part cement } 2 parts sand . }	52		Crushed	45	80
Immersed in water as soon as made, for seven days.					
3. Portland cement . } 1 part cement } 3 parts sand . }	52	Ditto	25	44	691
Immersed as No. 2.					
4. Pure Roman cement . . .	30	Ditto	27	48	746
5. Roman ce- ment . } 1 part cement } 2 parts sand . }	52	Ditto	3	5·33	83

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Size of Blocks, 9 inches by 9 inches ; Sectional Area, 81 inches.	Days old.	Remarks.	Crushing Force in Tons.		Lbs. per Square Inch.
			On the Sectional Area of 81 inches.	On the Square Foot.	
<i>Blocks of Concrete Stone.</i>					
6. Portland } 1 part cement } cement } 2 parts sand }	48	Cracked	24	42.6	664
7. Ditto ditto ditto .	270	Crushed (suddenly)	63.75	113.33	1.763
8. Portland } 1 part cement } cement } 3 parts sand }	70	Crushed	16.875	30	442
9. Portland } 1 part cement } cement } 10 parts shingle }	30	Ditto	10	17.77	276
<i>Nine-inch Piers of Brick, built in Cement.</i>					
10. Bricks and pure Portland } cement }	30	Crushed (soft bricks)	16	28.4	442.4
11. Bricks and } 1 part cement } Portland } 2 parts sand }	52	Crushed	22.5	40	608
12. Ditto, ditto { 1 part cement } { 2 parts sand }	30	Ditto	26.5	47	726
13. Bricks and pure Roman } cement }	30	Ditto	30	53.3	982
14. Bricks and } 1 part cement } Roman } 2 parts sand }	52	Ditto	14.062	25	386

FURTHER EXPERIMENTS ON 'COMPRESSION,' made at Mr. JACKSON'S Works on the 8th March, 1851, on BLOCKS OF PURE CEMENT, which were afterwards deposited at the GREAT EXHIBITION. The Trials were made on two Blocks of each sort of Cement, the result given being an average of the two.

Size of Blocks, 6 inches by 6 inches, and 12 inches long; Sectional Area, 36 inches.	Days old.	Remarks.	Crushing Force in Tons.		Lbs. per Square Inch.
			On the Sectional Area of 36 inches.	On the Square Foot.	
15. Pure Portland cement. .	40	Crushed	40	160	2.453
16. „ Atkinson's cement .	40	Crushed partially.	20	80	1.244
17. „ Sheppy cement . .	40	Crushed	19.5	78	1.213
18. „ Roman cement . .	40	Ditto	13.25	53	0.829

RÉSUMÉ OF THE FOREGOING EXPERIMENTS.

1st. Blocks of Cement, Pure and with Sand, Nos. 1, 2, 3, 4, 5.

		Tons.
Roman cement and 2 parts sand, bore on an average	5.33	per square foot.
Portland ditto and 3 parts sand, ditto	44	ditto.
Roman ditto, pure ditto	50	ditto.
Portland ditto and 2 parts sand ditto	80	ditto.
Portland ditto, pure ditto	146	ditto.

The relative order of strength of the different mixtures is exhibited in this Table, and as a matter of comparison—

Portland cement, pure, is three times the strength of Roman cement, pure.

Ditto and 2 parts sand, about one-and-a-half times ditto.

Ditto and 3 parts sand, equal to ditto.

2nd. Blocks of Concrete Stone, Nos. 6, 7, 8, 9, attained at six weeks old, the average strength of bricks, viz., 42 tons per square foot; while at nine months' old, the power of resistance to pressure is 113 tons per square foot, showing it to be little inferior to Portland stone. In these blocks, the cement is mixed with the sand in proportions of 1 cement and 3 sand, and the two materials occupy one-fifth in bulk of the whole mass.

3rd. Piers of Brick and Cement, Nos. 10, 11, 12, 13, 14. The greatest resistance in these experiments was found to be 30 tons on a 9 inch pier, giving as an average, 22 tons on this area, or 38 tons per square foot, as the resistance to crushing of brickwork in cement, the Roman cement being nearly always and the Portland cement invariably, stronger than the bricks.

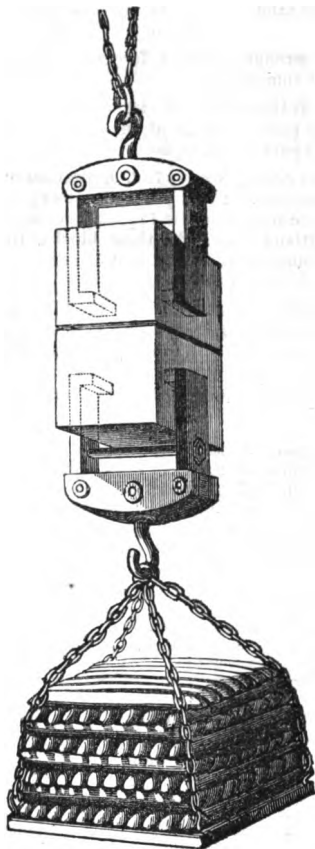
EXPERIMENTS on the relative 'ADHESIVE' POWERS of PORTLAND and ROMAN CEMENTS to different sorts of STONES. These Stones were all cubes of 6 inches, with an area of 36 inches superficial, cemented together by a joint varying from one-eighth to one-fourth of an inch thick, which was torn asunder by weight gradually applied to the lower stone (Fig. 2, p. 500). The result given is an average of two or more trials.

Description of Stone.	Age of Joint, in Days.	Weight in lbs. that tore Joint asunder.	Average resistance.	Resistance in lbs. per square inch.	Remarks.
1. Portland stone and Portland cement . . . A	50	4,526	5,276	146	The first pair of these stones, A and B, tested at Milbank, April, 1848, in presence of Mr. James Walker, (M. Inst. C.E.)
Ditto ditto . . . B	56	6,000			
Ditto ditto . . . C	900	5,302			
Ditto ditto . . . D	150	4,500			
2. Granite and Portland cement	50	3,593	3,435	97	D, tried at the Exhibition Building before the Jury of Class XXVII., Sept., 1851.
3. Bramley-Fall stone and Portland cement . . .	40	3,277			
4. Whitby stone and Portland cement	50	2,738	2,048	57	In all these cases, Nos. 1, 2, 3, and 4, the stones separated at the joint, but with a considerable portion of the stone, equal on an average to one-eighth inch in thickness, adhering to the cement.
5. Kentish rag-stone and Roman cement . . .	24	1,455			
6. Portland stone and Roman cement E	56	818	1,521	42	E and F, tested April, 1848.
Ditto ditto . . . F	56	818			
7. Granite and Roman cement	24	804	811	22	Block G, broken at the Exhibition, Sept., 1851, before the Jury of Class XXVII.
	56	818			

In these experiments it is to be observed, that the adhesiveness of Portland cement is greater to Portland stone, than to any other description of stone here experimented upon.

The average of three trials shows, that a force of 5,276 lbs. was required to tear asunder two blocks, 6 inches square, jointed with Portland cement; and 1,520 lbs., to separate two blocks of the same dimensions jointed with Roman cement, which gives an advantage in favour of Portland cement of $3\frac{1}{2}$ to 1.

Fig. 2.



EXPERIMENTS ON the 'COHESIVE' POWER of PORTLAND CEMENT and PORTLAND STONE, tried on BLOCKS shaped as in Fig. 3.

The sectional area at fracture was 2 inches by $2\frac{1}{2}$ inches = $5\frac{1}{2}$ superficial inches.

Broken before the Jury of Class XXVII. at the Exhibition Building, September, 1851.

Pure Portland cement broke with 2,280 lbs. = 414 lbs. per square inch.

Portland stone broke with 1,480 lbs. = 269 lbs. per square inch.

Fig. 3.

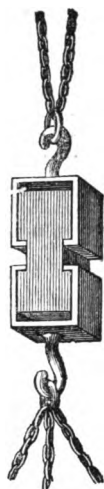
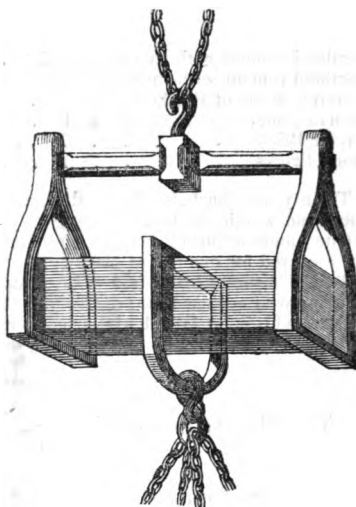


Fig. 4.



EXPERIMENTS on the resistance to 'CROSS' STRAIN, tried on BEAMS of PURE CEMENT, supported at both ends and loaded in the centre. (Fig. 4.)

Dimensions, 18 inches long, 4 inches deep, by 4 inches thick; net bearing, 16 inches.

Sectional area, 16 inches.

Tested before the Jury of Class XXVII., September, 1851.

—	Breaking Weight in lbs.	Weight per Square Inch.	Age.
Portland cement . .	1,580	99	25 weeks.
Sheppy cement . .	980	61	Ditto.
Harwich cement . .	380	24	Ditto.
Portland stone . .	1,280	80	Ditto.

MEMORANDA with reference to PORTLAND CEMENT, &c.

Concrete made with Portland cement one part, shingle ten parts	weighs about 139 lbs.	per cubic foot.
Concrete made with rubble stone, Portland cement, and sand	„ 135 lbs. to 140 lbs.	„
Portland cement and two parts sand	„ 127 lbs.	„
Roman cement and two parts sand	„ 120 lbs.	„
Brickwork in cement . . .	„ 110 lbs. to 115 lbs.	„

AMOUNT of ABSORPTION by different SUBSTANCES tried on Blocks of 1 Foot Cube, immersed in Water, at thirty days old.

	Date when Absorption ceases.	Gain in Weight, after Immersion.
Portland cement with two parts sand	7th day	1 per cent.
Portland cement with three parts sand	10th day	1½ „
Concrete stone of Portland cement	20th day	4 „
Roman cement and two parts sand	10th day	5 „
Pavior Bricks	8th day	6½ „
Stock Bricks	8th day	11½ „

Twenty-one bushels Portland cement in a dry state, measure one yard cube, and weigh one ton.

One hundred bushels cement and sand, or about five yards, measured dry, are required for one rod of brickwork.

Thirty bushels cement and sand, measured dry, are required to make one cubic yard of cement mortar.

Portland cement mixed with from four to five parts of sand, and the necessary quantity of water to form mortar, diminishes in bulk 30 per cent.

The following TABLE applies to one rod of BRICKWORK in PORTLAND CEMENT.

PROPORTION.				Bushels Cement per Rod.	Cost per Rod, for Brickwork in Cement. Cement and Sand only.	Cost per Cubic Yard of Portland Cement Mortar, without Labour.
					s. d.	s. d.
Five parts of sand to one part of cement, take 17				17	55 0	16 6
Four ditto one ditto				20	66 0	19 0
Three ditto one ditto				25	80 0	22 6
Two ditto one ditto				33	90 9	28 6

The cement is reckoned at 2s. 6d. per bushel; the sand at 3s. per yard.

Lieutenant-General SIR CHARLES PASLEY said, that in 1826, when practical architecture constituted a part of the studies of the young Engineer Officers at Chatham, his attention was drawn to this subject. At that period, the most contrary opinions were advanced with respect to hydraulic limes, and the only satisfactory observations were those made by Smeaton at the Edystone Lighthouse. He was then induced to experiment upon artificial cements: he tried various proportions of chalk and clay, but failed in consequence of his not being accustomed to chemical manipulation. In 1828, he was requested by Colonel Reid to repeat those experiments, and by accidentally combining the chalk with the alluvial mud of the Medway, he produced, to his great surprise, a cement, which subsequent experiments brought to considerable perfection, and of which, in 1830, he printed a description for private circulation. In the same year, Mr. Frost, who entertained M. Vicat's opinions of the superiority of blue lias lime, and who then had the manufactory at Swans-

combe, now in possession of Messrs. White and Sons, was induced, by his recommendation, to adopt the new process. In 1837, he pointed out to Mr. White the causes of failure of some cement, and that gentleman expressed a doubt, whether any that was made artificially, could ever equal the natural cements, but General Pasley proved, on the contrary, that it was stronger than the best Roman Cement. His process was used in the preparation of Greaves' blue lias cement, a fact of which he was not aware till the year 1844, when he happened to be inspecting a branch of the London and North-Western Railway, where it had been employed. In 1845, the lithic cement was used at Manchester by Messrs. Evans and Nicholson, and it was said to be the produce of chemical works. On examination, it turned out, that the same proportions of lime and clay were employed as in his process, and that the addition of the refuse of the chemical works, in nowise altered, or improved the material. The cement exhibited by Messrs. Robins and Aspdin also appeared to be very good.

The comparative trial mentioned in the Paper, would, he thought, have been more conclusive, if the beams had been similar in both cases, and it must be remembered, that no experiments with Roman Cement could be relied on, unless its age were correctly ascertained. His object had been to produce a cement resembling what was called Roman Cement, and he congratulated himself, that his endeavours had led to the introduction of a cheaper and better quality, and that by its adoption in France, the theory of M. Vicat had been practically refuted. Another great advantage attending the process, was the improvement in the navigation of the Medway, by the constant removal of deposit from the bottom. Mr. White's practice surprised him in one respect, that strong cement should bear a greater proportion of sand than lime, nor could he understand the statement in the Paper, that in order to make good concrete, cement should set slowly. There was no particular aptitude in cement, to adhere to one kind of stone more than another: it made, indeed, little difference whether the stones were polished, or not. The largest masses of masonry might be put together either by artificial, or natural cement, and had Smeaton been aware of this fact, it would have saved him the trouble of dovetailing the stones, in the construction of the Edystone Lighthouse.

Mr. HAWKSHAW was of opinion, that the hoop-iron in the beams destroyed the value of the experiments, as a great proportion of the resistance would be due to the iron, and as it was not similarly disposed in both cases, no conclusion could be drawn as to the relative strength either of the beams, or of the cements. He did not understand the division of cements, into natural and artificial; all

those used by Engineers and Architects were artificial cements. The force required to crush compact limestone, was very much greater than 700 lbs. per square inch, accorded to it by Vicat.

Mr. WHITE explained, that the term 'natural' cement was applied to the material manufactured from the argillo-calcareous nodules, known as cement stone, and found abundantly in England; while the 'artificial' cements were composed of the separate substances, lime and alumina, combined in any given proportions, according to the will of the operator.

Mr. GIBBS said, that no analogy could be established between the two beams, for hollow bricks allowed the carbonic acid to penetrate in a very short time, whereas solid masonry could not set so quickly. He thought that the bridge at Maidenhead would not have exhibited any symptoms of subsidence, if it had been constructed of hollow bricks, but the masonry being solid, sufficient time was not allowed for its setting before striking the centres. The quality of the Portland Cement appeared to be excellent, and it was evidently a great improvement on the others.

Mr. GRAVATT thought, that no satisfactory conclusions could be drawn from the experiments, as there were three elements to be taken into consideration:—the hollow bricks, the iron, and the cement. The adhesion of cement to stone was, in a great measure, independent of the fineness of the surface, but when applied to bricks, they should be clean and damp, for any sand between them would be like so much dry glue. There was as much difference between cementing hollow bricks, and cementing stock bricks, as in glueing together pieces of steel, or pieces of wood. The real test of the strength of a cement, was to attach the bricks together one under the other, and to suspend the whole perpendicularly. During the construction of the Thames Tunnel, sometimes as many as four hundred experiments were made in a week, every cask being tested. The brickwork was built in equal parts of Roman Cement and sand; it was perfectly hard at the end of a week; after six months, it became much softer, but at the end of a year, it recovered its former hardness. The middle pier was first constructed solid, and the side arches were cut through after an interval of about six months, as it would have been very difficult to have done so either before, or afterwards.

Mr. J. D. HOPKINS observed, that it was very unfortunate for the success of the experiments, that the bricks were not of the same description in the two beams; there were many disadvantages in the mode adopted of bonding the hollow bricks. He did not think, that the different position of the hoop-iron had greatly influenced the results, as it only amounted, in both cases, to a bar, $1\frac{1}{2}$ inch by 1 inch.

504a

DAYS

15 16 17 18 19 20



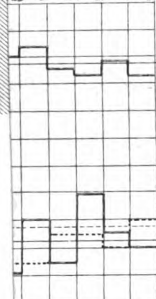
Average.

DRY. IMM^{sd}.

400	350
450	550
500	450
500	370
400	350
450	320
450	400
450	250
500	350
500	250
500	350
400	300
400	400
400	450
300	400
400	400
300	400
450	340
400	400
400	400
20	3,550
Avg ^e	427 — 374

DAYS

15 16 17 18 19 20



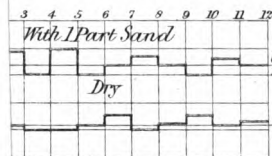
Average

SAND. DRY. IMM^{sd}.

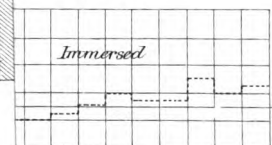
320	750	650
230	850	750
230	900	700
230	850	700
200	650	750
150	950	800
300	850	800
190	900	800
150	975	930
200	900	850
200	850	800
300	950	800
230	900	800
230	875	875
200	975	350
130	925	350
250	950	850
250	700	850
220	850	900
250	900	800
20	4,550	17,250
Avg ^e	227 — 862	— 815

TABLE 4.

N CEMENT AT 7 DAYS

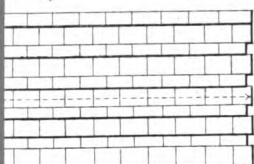


DITTO



Days { Dry..... 376 lbs
t { Imm^{sd} 340 " } Average
t Sand, Imm^{sd} 154 " }

1 Pt Sand	Neat
IMM ^{sd}	DRY. IMM ^{sd}
200	390
150	365
110	375
200	400
100	400
200	370
150	345
120	400
150	385
200	355
120	380
150	365
12	1,550
Avg ^e	154 — 376 — 340



Stone

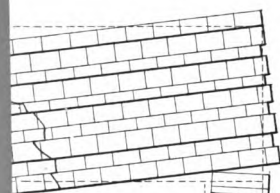
Concrete

Ground

Concrete

14 15 16 17 Feet

DOWN.



Concrete

Mr. J. LOCKE, M.P., V.P., thought the objections which had been made, were well founded. There was no doubt, that the different distribution of the iron altered the composition of the beams, and that the hollow bricks, by allowing the admission of the air, materially affected the result in that particular case. But the most important object of the Paper, was to advocate the employment of good cement in the construction of hydraulic works. He was both surprised and pleased at the account given in the Paper, of the employment of this cement at the Digue of Cherbourg, and of the enormous masses there created by its help. Such a material could not fail to be most useful in hydraulic works. Greater experience was continually changing the views of Engineers, and had this cement existed in the days of Smeaton, it would, no doubt, have caused an alteration in his practice. Mr. Hartley of Liverpool, whose vast experience was well known, was now using common rubble with good cement, instead of constructing the quay walls as formerly, in solid ashlar, and the expense was thus considerably reduced.

Mr. FRANCIS must add a few words in favour of Medina Roman Cement, with which, during the last fifty years, the most important works in this country had been executed. It had been employed in the construction of the Thames Tunnel, in the foundations of the centre pier of the Britannia Bridge, in the works at Cherbourg, the harbours of refuge at Dover and Alderney, &c. At the Isle of Wight, a retaining sea groyne, 200 feet in length, had been constructed with a remarkably small quantity of Medina Roman Cement and sea-beach; and it had for the last four years, withstood the violence of the sea. The great value of this cement consisted in its proper quality of setting quickly.

Captain FITZROY, R.N., thought, that some light might be thrown on the nature of cement, by the use of the microscope and goniometer, which had elucidated several points in Geology. The mechanical arrangement of the particles might thus be ascertained, and also whether they assumed crystalline forms, or whether they had undergone some chemical, or magnetic change. In the South Sea Islands, very large statues had been found, evidently formed of an artificial substance, of which it would be highly interesting to obtain an exact analysis. Old cements might be usefully submitted to a similar examination, also specimens of old moles and of other works of the ancients, which might prove to be artificial.

Mr. WHITE, while admitting that it would have rendered the comparison easier, if the beam tested at the Exhibition had been constructed like the other, of solid bricks, thought there was less importance to be attached to the presence of the hoop-iron in the

beams, than had been supposed, since its collective amount was only equivalent to a bar of $1\frac{1}{2}$ inch by 1 inch, and a certain portion of the iron was, by mistake, disposed above the line of the neutral axis and became, therefore, practically useless.

Neither did he consider that the loss in solid content, resulting from the use of hollow bricks, was compensated for by the introduction of air through the interstices, which, it had been argued, would tend to harden the cement quickly. It was to be remembered, that the setting action of cement was not due, as in the case of mortar, to carbonization by the atmosphere, but to the chemical formation of a double silicate of lime and alumina, acting alike on every part of the cemented mass. The quantity of carbonic acid in the-atmosphere was small, and its action was powerless, except on the outer crust of the cement, which it penetrated to the extent only of 1-32nd of an inch. This penetration was rendered apparent by a change in the colour of the cement, and its influence was most felt on soft and porous cements. He considered, therefore, that, in the Maidenhead bridge, the use of hollow bricks could only have prevented failure, by their weight being less, or the load being differently distributed, and not by the opportunity they would have afforded for a speedier induration of the cement.

The hardening process with all cement was a gradual one, and was to be distinguished from the setting process which might be considered immediate. As a rule, the natural cements were quick setting. Cement might set too quickly, from its being underburnt, or ill prepared, in which case, it would, in the language of the workmen, 'give again,' and become soft after working. This change was rapid, and when once effected, the cement would never thoroughly harden, though it would dry in time. It was quite contrary to his experience, that cement should harden at first,—become soft in six months,—and harden again in an interval of twelve months. This was not the characteristic of good cement, and if the observations had been properly made, it could only be supposed, that the material was defective in the first instance.

The experiments and suggestions of Sir Charles Pasley had been very serviceable in drawing attention to the use of artificial cements in this country, but at the same time, it should be understood, that the cements made by General Pasley, or by Mr. Frost, were not identical with the material now known as Portland Cement. The constituents of the three cements were however similar, and they differed but little in the proportions employed: but both Sir Charles Pasley and Mr. Frost stopped short at the all-important point of calcination, and they rejected that part of the kiln as overburnt, which

was now found to yield the most valuable product. The aim of Sir Charles Pasley had been to rival the natural cement, and he had succeeded; but it had been reserved for another operator to produce in Portland Cement, a material which should far outstrip in cohesive power, any of the natural cements known in this country.

Mr. White found it difficult to concur in the opinion, that the introduction into France of this artificial cement, was a refutation of M. Vicat's theory as to limes and cements. That M. Vicat had a preference for the employment of limes, was undoubted, but not to the exclusion either of natural, or artificial cements. His labours, in fact, had been directed like those of General Pasley to the production of an artificial compound which, in setting slowly and attaining great eventual hardness, should combine the properties both of a lime and a cement; and, his researches, as published from time to time in the '*Annales des Ponts et Chaussées*,' were alike honourable to himself and beneficial to science. M. Vicat was ever ready to appreciate the labours of others, and that he recognised peculiar properties in the Portland Cement and valued it accordingly, was shown by the desire he had lately expressed, to be furnished by Messrs. White with all the particulars of its fabrication.

Allusion had been made to a cement manufactured at Manchester, called lithic cement. Its components were lime and clay, as in other cements, but to these was superadded the chromate of iron, a chemical residue which increased the hardness of the cement, but gave it, at the same time, so unpleasant a colour, that it could only be used for brickwork and not for plastering purposes. Much of the clay used in the manufacture of Portland Cement, was impregnated with iron, a disadvantage rather than otherwise, since the percentage was too feeble to materially augment the strength, while the colour it imparted, interfered with the grey tone so much esteemed in that cement. Cements that did not contain a large proportion of lime, like Portland Cement, were undesirable for concrete: hence ordinary Roman Cement was not employed for that purpose. It was essential to its eventual hardness, that concrete should set slowly, and the opportunity was thereby afforded of punning the concrete, whether used *en masse*, or in moulds; but it was important not to disturb the crystallization, when it had once commenced.

He differed with the opinion that had been expressed, that cement adhered with the same force to all stones alike and experiment had shown it to be erroneous. The porous nature of certain stones, such as the Portland and the Kentish rag, caused the cement to adhere to them as perfectly as to brick, whilst to the more intractable stones, such as granite and the harder sandstones, the adhesion was

remarkably slight. It should be borne in mind, that the setting of cement was mechanically aided by the evaporation of the water used in mixing it. Any substance, therefore, like dry stone, or porous brick, that helped this absorption, was peculiarly congenial to the cement, while hard, or polished surfaces such as glass, or marble, were very imperfectly united by water cements, though they could be effectually joined by oil cements, or other substances, the operation of which was to effect union by the exclusion of the air. Upon the whole, he could not regret, that the experiment had been made, as it exhibited hollow bricks in contrast with solid bricks in a position they had not hitherto occupied, without suffering by the comparison. The adhesion of cement to the hollow bricks, was as perfect as it was to the solid bricks. If however, the brick beam was not to be regarded as a satisfactory test of the value of the cement, the experimental tables in the Appendix to the Paper might confidently be appealed to, as exhibiting the cement under the action of pressure and of cross strain, as well as demonstrating its cohesive strength, and its power of connecting other bodies. Under all these conditions it exhibited a manifest superiority over ordinary Roman Cements, which though excellent of their kinds and useful, where quickness of setting was an object, were rapidly giving place to the stronger but more costly material known as Portland cement.

Mr. White then called attention to a Paper on the subject of cements, contributed by Dr. Schafhaeutl, of Munich, to the German Polytechnic Journal of November 1851, and since published by him in the form of a pamphlet. In bearing testimony to the general accuracy and importance of the statements contained in that Paper, and in expressing his admiration of the comprehensive view therein furnished of the history of cements in England, he could not refrain from noticing some remarks which reflected invidiously not only upon the cement-manufacturers of this country, but also on those who had occupied themselves with cements as a subject of scientific investigation. In a letter to Mr. C. Manby, the Secretary of the Institution of Civil Engineers, Dr. Schafhaeutl complained, that when in London, during the period of the Great Exhibition, though he had taken great pains to become acquainted with the nature and properties of Portland Cement, it was only with difficulty that he succeeded. Relying, however, upon the information obtained from a manufacturer of Roman Cement only, and on the published experiments of General Pasley upon artificial, (but not on Portland,) Cement, made fifteen, or twenty years ago, he impugned the correctness of trials made by Messrs. White, and gave an opinion, that the so-called Portland Cement was not superior to the well-known and long-tried Roman

Cement. Now if an opportunity had been afforded, Messrs. White could have adduced reasons for the superiority of Portland Cement, which had not even been hinted at by Dr. Schafhaeuti's informant, and which were not to be found in the work of Sir C. Pasley, who had never claimed for his artificial cement, a superior strength to that of the natural cements.

It was quite evident, that Dr. Schafhaeuti was unacquainted with a feature in the preparation of Portland Cement, which was, in fact, the distinguishing peculiarity of the material, viz., the degree of calcination employed in its manufacture, which by nearly approaching to vitrification, involved peculiar chemical changes and combinations, not shared by the natural cements when treated in a similar manner. Ignorant of this fact, he had attributed the superiority claimed for Portland Cement, to the presence of a larger percentage of natron, or soda, than was found in the natural cements, the difference, according to Dr. Pettenhoffer, of Munich, being 2.00 of soda for Portland Cement and only 0.25 in the Bavarian cement. Now while it was granted, that the combination of soda with silica, at a high temperature, would, if it existed in sufficient quantities, impart great hardness to the cement, it was by no means clear, that soda uniformly existed in Portland Cement, in quantities sufficient to produce such an effect, for in other analyses made of this material, particularly that by M. Vicat, no trace of soda was found; hence the inference might be drawn, that its peculiar characteristics were referable to other causes. In another part of his pamphlet, Dr. Schafhaeuti expressed a doubt, whether the experiments made by Messrs. White on Roman and Portland Cements, accurately exhibited the relative merits of the two materials, assigning as his reason, that being manufacturers of Portland Cement only, it was natural for them to depreciate the other. That suspicion would not however attach to them in this country, where it was known, that they were equally interested in the production of both cements; and even if such were the case, there were statistics published by other Portland Cement manufacturers, which showed the experiments of Messrs. White, to be under, rather than overstated. It was to be regretted, that in a published document, quotations from other sources should be inaccurately made, but in the pamphlet in question, the adhesive force of Portland Cement to Bramley Fall stone was stated to be 36 lbs. to the square inch, while in fact, the result obtained, and from which the quotation was made, was 76 lbs. per square inch. To the assumption, that English manufacturers owed the success of their cements to chance, while to the French and the Germans, exclusively belonged the merit of analytical investigation, there was the practical reply, that Portland

Cement was, at this time, being exported in large quantities, from England, both into France and Germany, and was eliciting from the Engineers of both those countries, the most flattering testimony of its superiority to any native production, either natural, or artificial.

Mr. RENDEL,—President,—said, that the introduction of these cements had, undoubtedly, caused Engineers to employ cut stone much less frequently. Mr. Hartley, at the commencement of his career, thought it necessary, for insuring solidity, to use cut stone blocks of large size, where he now used rubble and cement. Time was a great element in the consideration of the choice of a cement; the cheapest was that which gave the requisite result the soonest. If plenty of time could be allowed for hardening, the blue lias lime would be the most economical; in the opposite case, the choice would lie between the Roman and the Portland Cements, the latter of which partook more of the character of a lias, whilst the former was useless, if once disturbed. If an Engineer desired merely to stop a hole, he would use Roman cement; but this was an exceptional case. He thought, that each cement might find its peculiar application, and that experience would point out the circumstances for which each was more particularly adapted.

May 25, 1852.

The session terminated with a *Conversazione* given by the President, to the Members and a large number of visitors, in the rooms of the Institution, which presented an interesting collection of works of art, and of models of engineering constructions and of machinery.

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